CALITOO

SunPhotometer

User Manual

Version 3,0

October 2020

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Please read this manual carefully before using your photometer.

This manual as well as technical informations, tutorials and software configuration of the photometer are available on our website :

http://www.calitoo.fr

Summary

Introduction

This document allows you to take control of the photometer CALITOO and make measurements with a scientific value. Its use is suited to the terrain and the manipulation of public schoolchildren under the Calisph'air operation.

Calisph'Air[(1)] is an educational project for the **study of the atmosphere and climate** that accompanies **satellite missions** to study the atmosphere Parasol, Calipso, IASI …

This project is developed within the framework of **educational and scientific international GLOBE program**[(2)], which brings together students, teachers and scientists around the observation and collection of environmental data. GLOBE brings together through the Internet, more than 15,000 schools and 26,000 teachers worldwide.

The program has a study of aerosols, with Calipso data as well as measurements from the ground, with a sun photometer.

(1) https://enseignants-mediateurs.cnes.fr/fr/calisphair

(2) https://www.globe.gov

In the first part, we will guide you in using the photometer.

The second part, describes the use of PC software: downloading data and using display and data processing tools.

The Appendix section presents the scientific basis for the calculations, the technical characteristics of the device as well as the installation sheets for the software on different computers.

Revisions

Version 3.0 – October 2020

- Calinet tool

  - Push your measurements onto the Calinet server to view the results of a set of photometers over a selected period of time and at a specific geographic location.

Version 2.9 – October 2018

- Aeronet Inter-calibration tool :

  - Read version 2.0 and 3.0 of Aeronet data files.

  - Inter-calibration validation by comparing Aeronet and Calitoo AOT.

- Monitoring tool :

  - Possibility to measure in High Sensitivity mode to perform particle detection experiments with reasonable power lamps (5 Watt).

- Calibration :

  - The calibration log recorded on board each photometer can be consulted in the CNo tab of the main window.

Version 2.5 – October 2016

- Display on the photometer of the Angstrom coefficient when taking measurements and reading the data.
- "Visu" tool is upgraded with the "Angstrom" button to compute and display the Angstrom coefficient of each measurement point on a small graph and a gauge.
- “Export” tool to collect all the data of a photometer in a zip file to be exchanged with other people.
- “Import” tool to import a photometer zip and visualize the data of this photometer with Calitoo PC software.

Version 2.0 – October 2015

- Monitoring tool to display the photometer data in real time on a curve.
- Inter-calibration tool for calibration with professional standard photometers (Aeronet).
- AOT-Calculator tool to compute AOT by manually entering all other parameters.
- AOT Processing tool to re-compute the AOT of old measurements after a new calibration.
- Uses the decimal separator of the host computer.
- Ability to update the firmware of the Calitoo device via internet.

Version 1.2 – March 2015

- Change of format of the date and time to respect the international format (ISO8610).
- Ability to work with the data of a photometer without connecting the photometer to the PC.
- "Visu" tool to view data in the form of curves.
- 'Langley' tool for Langley calibrations of the photometer

Version 1.0 – September 2013

- Downloading the photometer data to a PC

1 Starting with Calitoo

1.1 Batteries

The photometer uses 4 AA batteries located under the hatch at the rear of the unit.

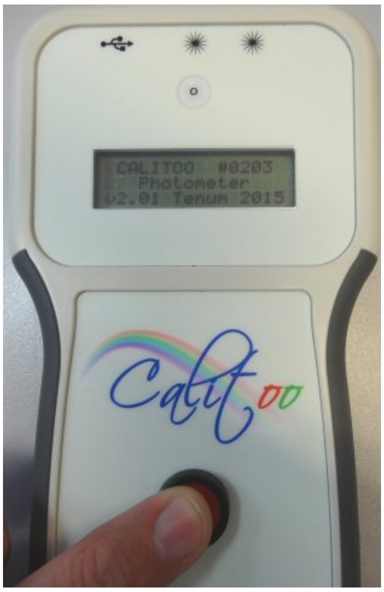
The installation is made easier by placing the'+' side of the battery in its housing first.

You can also use AA rechargeable batteries.

When your photometer is not used for a long time, we recommend that you remove the batteries. Indeed, some battery brands degrade over time and damage the contacts of the housing.

1.2 Power ON

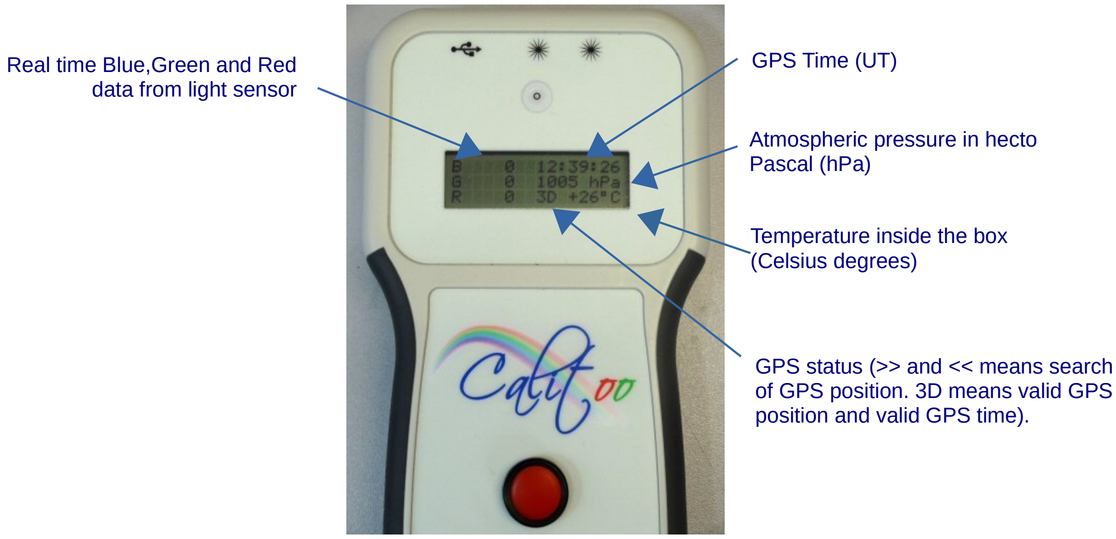
The photometer is turned on by pressing for 2 seconds on the center button.



As soon as the text appears, you can release the button and the unit is in operation.

1.3 First measurements

After turning the welcome page, the photometer indicates that it is in measuring mode and displays basic information :



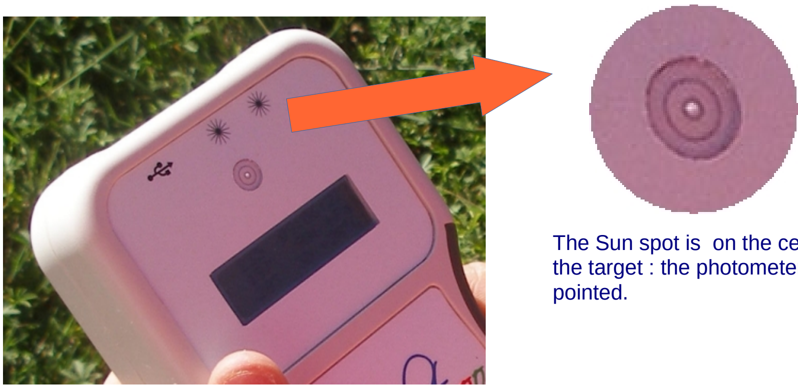
Once the GPS photometer is 3D, you can start measuring.
If the GPS is not in 3D, you cannot make a recordable measurement

1.4 Point to the Sun

Pointing the photometer is manual, it is facilitated by the sighting device located above the LCD screen.

Video tutorial on YouTube : [How to measure aerosols ?]

You have to stand facing the Sun stably and quickly bring the bright spot in the middle of the target pointer and keep the same time measures.



The Sun spot is on the center of the target : the photometer is pointed.

1.5 Maximum

The goal is to get the maximum value in three colors during about 1mn of search.

Click the button on the photometer and you go to the page maximum measurements (assuming of course that you had stayed on the base page described above).

While keeping an eye on the target, you monitor the numerical measured values on the screen. When maximums do not change, after about one minute, you go on to the next step.

1.6 AOT display

After displaying maximum values page, by pressing one more time on red button, Calitoo computes AOT and displays results on a new page.

If results seems be wrong for you, you can choose to do not recording it (see section 1.8)

1.7 Alpha display

Click on the button again and you are on the fourth page, the page of the Alpha parameter or Angstrom coefficient.

This coefficient, the calculation of which is explained in Appendix 4.2., makes it possible to characterize the type of particles detected.

R2 is a certitude index. 1.00 is a total certitude with the calculated Alpha while 0.50 is 50% of certitude.

R2 calculation is explained in Appendix 4.2.

1.8 Memorization

Click the button again and you are on the fifth page that is recording. You can read the complete sequence of operation of the button in the Appendix 4.6.

The photometer will ask if you want to record (the measures).

If this is the case, you should always press the button, but this time hold it down until **Recorded !** appears at the bottom of the screen.

Then you release the button and find yourself on the base page for a new round of measures.

If you are not satisfied with your measurement and you do not want to save, a single click will cancel the operation and you find yourself back on the base page for a new measurement cycle.

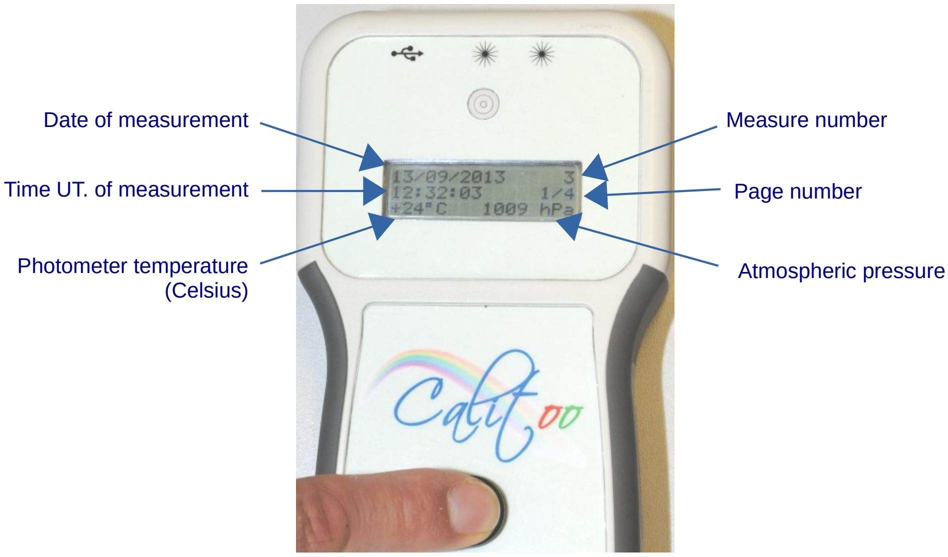
1.9 Reading data

To read the latest measurements, you go to the basic page and do a long button press on the photometer.

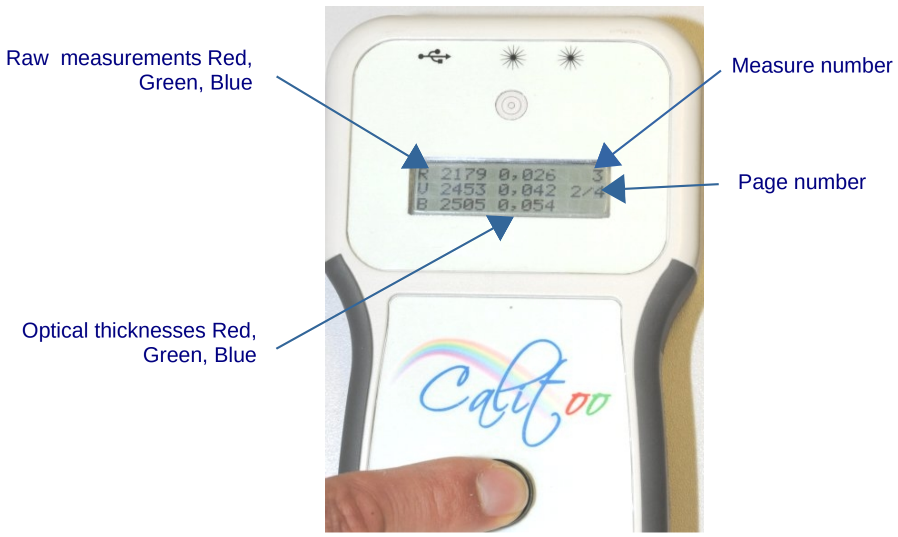
As soon as he tells **Mode READING** you release the button.

Every step, starting with the most recent, is presented in 4 pages :

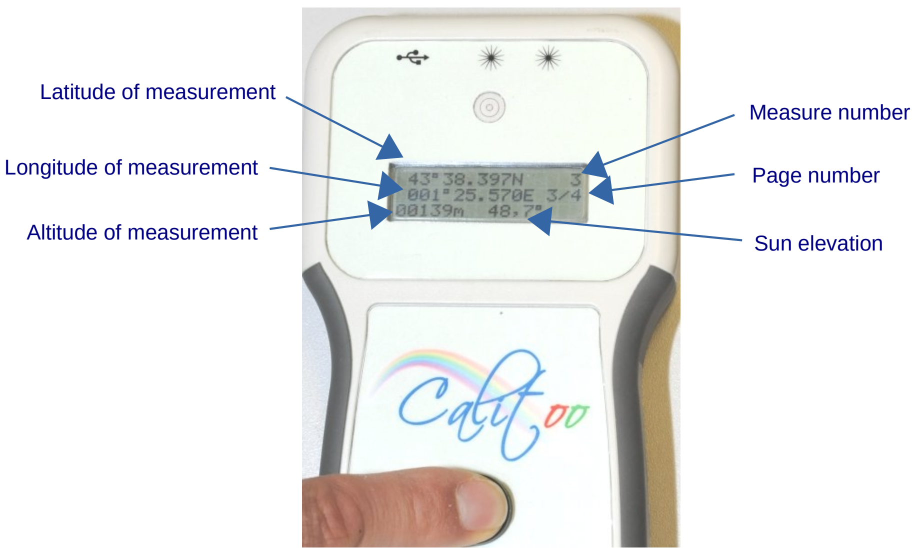
Page 1/4



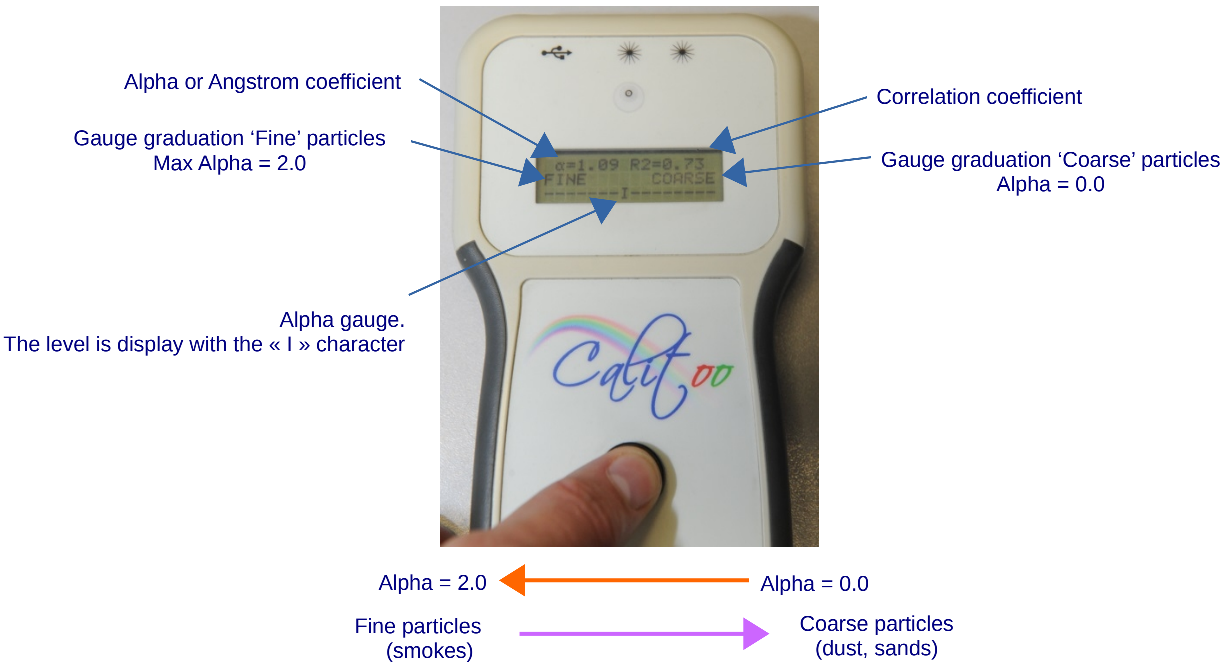
Page 2/4



Page 3/3



Page 4/4

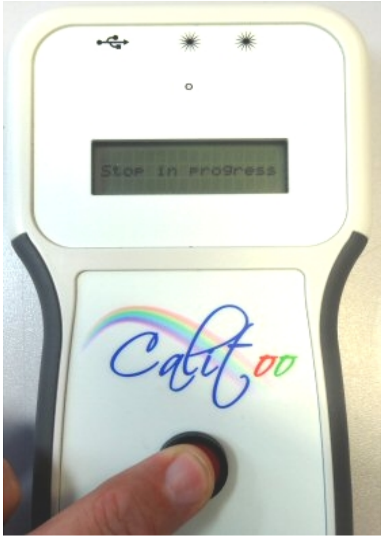


1.10 Mode change

To switch back to the **Mode MEASURING**, you have to long press the red button. Release the button when the new mode is displayed.

1.11 End of working

To turn off the photometer must be left long press the button to the message: **Stop in progress**... Release the button and the photometer is turned off.

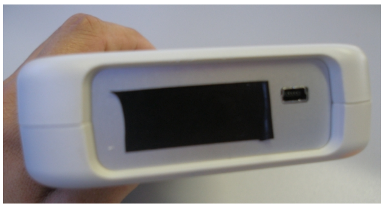


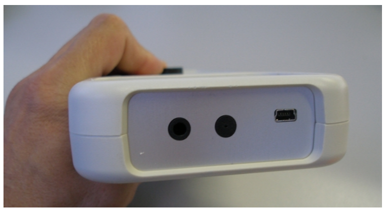
When the photometer is stand by during 30 minutes at least, it automatically turn off to preserve battery power.

1.12 Cautions

Your photometer is an optical measuring instrument and should not hinder the path of sunlight to the sensor.

To do this, we deliver with an adhesive in front of the holes in the viewfinder and the sensor. After use, we strongly recommend that you do the same.





Do not forget to remove the tape to your measurements 

2 PC software

2.1 Downloading and install

The PC software used to download data from photometer and process measurements is freely enable on our web site.

We have written Windows, Mac_OS and Linux versions.

We guest you to read tutorial sheet of each operating system you can found in Appendix of this user manual : Windows, Mac_OS, Linux.

Before starting the program, it is imperative connect the photometer PC and turn it on.

2.2 Start the software

A double click on the icon starts the software which tries to establish the software connection with a connected photometer. If it is not recognized, and if there are other USB devices connected (different from a keyboard and mouse and USB flash drive), try unplugging them and leaving only your Calitoo.

Once the operation is successful, the screen displays the photometer **CONFIG** mode and the program indicates the serial number of the photometer connected (Figure 2).

It is possible to start without connect the photometer (see §2.3.2)

The software offers through the following tabs :

Identity : Indication of unique serial number identifying the photometer. It will be included in the data files produced.

Data : Management of stored data (download and delete)

No : calibration parameters (No.) of the three measurement channels.

Rayleigh : Parameters for the calculation of molecular diffusion coefficient in calculating the optical thickness of the three measurement channels.

Ozone : Parameters for the calculation of the contribution of ozone in the calculation of the optical thickness of red and green (blue is negligible).

Tools : Open access of a tools set for measurements processing and calibrations operations.

Figure 2

2.3 Data downloading

2.3.1 Data staying in photometer memory

Downloading data is proposed in **Data** tab of the software (Figure 3).

A single click on the folder icon and the operation is started (Figure 4).

Figure 3

Figure 4

2.3.2 Working with data without connecting the photometer

You can use the software without connecting the photometer to the computer.

If the software does not detect a connection with a photometer, he suggests :

Figure 5

It is possible that despite all, the software initiates a connection with a search of Calitoo (**Figure 1**).

Just click on the question mark icon to perform a direct link to the data folder of your photometer or if you have more than one device, a list of numbers of photometers to choose from.

Figure 6

2.4 Data erasing

The brush and memory icon erases all 999 measurements in the photometer memory.

The program asks you to confirm (**Figure 7**). If your answer is OK, deletion is performed.

WARNING : The deletion carried out is final

Figure 7

2.5 Scientific parameters

2.5.1 Calibration operation

Your Calitoo is sold calibrated. The calibration parameters are stored in the photometer and are visible on the web site www.calitoo.com, in the Calibration tab.

Be careful if you change these values, knowingly or after a new calibration or if you notice any differences with calibration parameters online.

To send the new values to photometer you have to edit it and to click on the submit button.

They will be stored in the photometer even after a power off and used for calculations of optical thicknesses of the new measurements.

Measurements made before this change will remain unchanged. If these must be rectified, the only way is to redo the calculations with the **AOT Processing** tool described below.

Parameters are:

- **CNo** : is the numerical value that give your photometer if it came out of the Earth's atmosphere (Figure 8).
- **Rayleigh** : is a coefficient that takes into account the distribution of light at a specific wavelength by the molecules of the clean air (Figure 9).
- **Ozone** : is the contribution of stratospheric ozone to the optical thickness. It is zero for blue (Figure 10).

For more information of calculation method,
read in the annexes :**4.1 Optical thickness calculation**

Figure 8

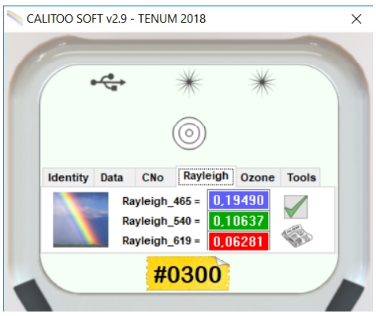


Figure 9

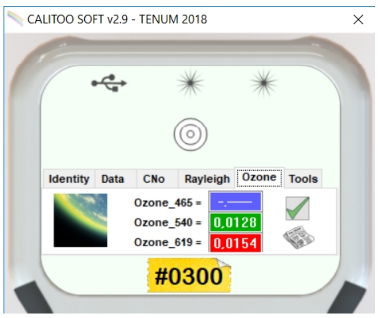


Figure 10

2.5.2 Calibration history

The News paper icon displays the calibration history on a drop-down panel. This history is part of the photometer and is stored in its flash memory.

It is completed after each new calibration of the type mentioned.

The text can be selected, copied and pasted into another text editor.

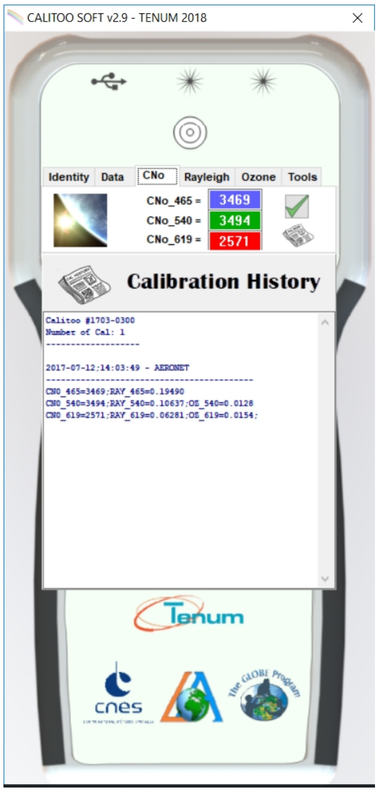


Figure 11

2.6 Work ending

To quit the configuration and data management, just close the main program window.

3 Toolbox

The last tab offers a software toolkit.
Click on the toolbox icon to see available tools :

We use some of these tools for the calibration and adjustment of photometers during manufacture. We put at your disposal as they can be used with different objectives:

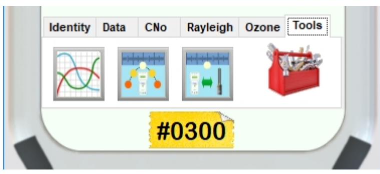
Teaching goal : Your students can experience the calibration methods, make autonomous measurement devices, etc.

Autonomy and quality : You can maintain a good quality measurement by making or doing calibrations over the world.

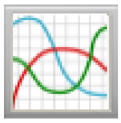
Here is a description of the seven tools in this software release :

- Data display
- Monitoring
- Langley type calibration
- Aeronet Inter-calibration
- AOT calculator
- AOT processing
- Import/export data from other photometers devices

The software displays on the tool tab, the three most used tools to facilitate their access. Be careful, during the first use, you have to open the toolbox to choose your primary tools.

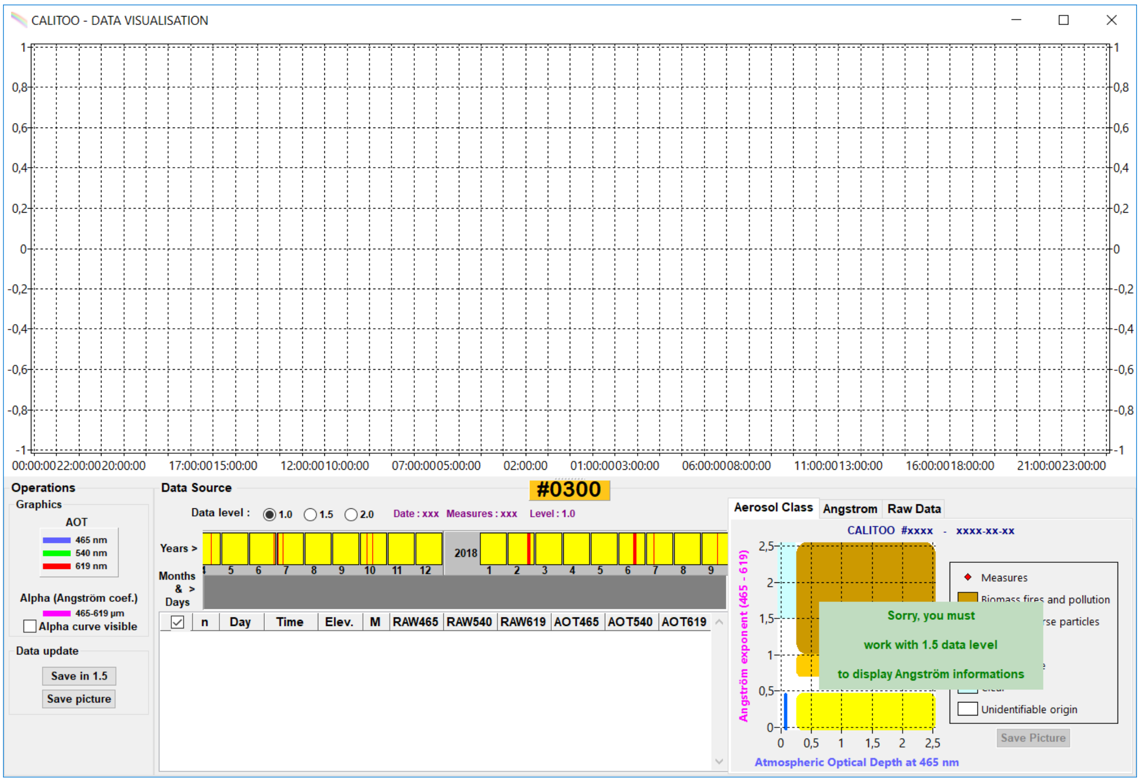


3.1 Data Visualization



After taking measurements of optical thicknesses, it is important to quickly view the data in the form of curves to begin their processing and interpretation of results.

3.1.1 Displaying data curves



Here is the window appears on the screen just after clicking on the icon **Data visualization.** It is composed of the following items :

Operations panel

Indicates the legend of the displayed curves and allows the display of the Alpha curve or Angstrom coefficient (aerosol particle size) and allows the data to be saved in a file after processing (Level 1.5).

Data Source panel

Panel Indicates the presence of available data. These data are previously downloaded from the photometer selected.

You choose the period of the measurements to visualize in a few clicks.

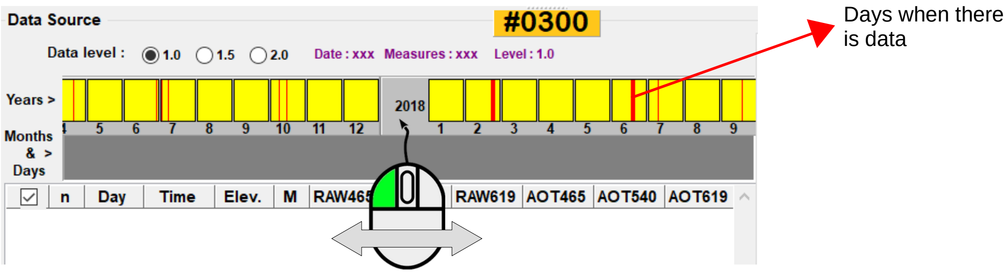
The data related to your choices are rows in a table below the calendar.

Right panel with tabs

Allows the reading of raw data and gives access to the results of different treatments concerning the size of aerosols.

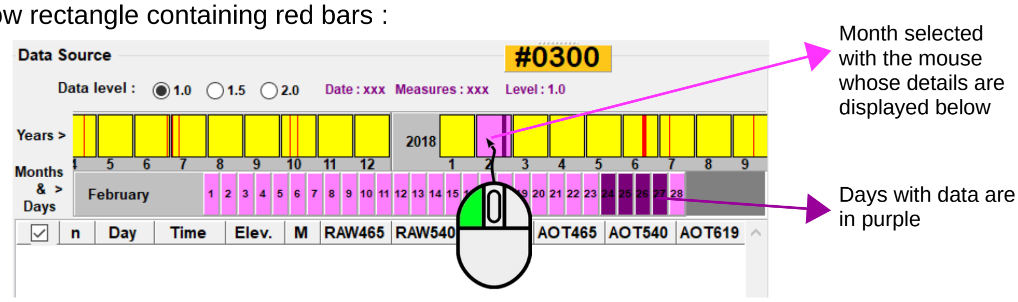
3.1.2 Select measurements period to display

The graphic calendar allows you to see at a glance whether or not a photometer data is available :

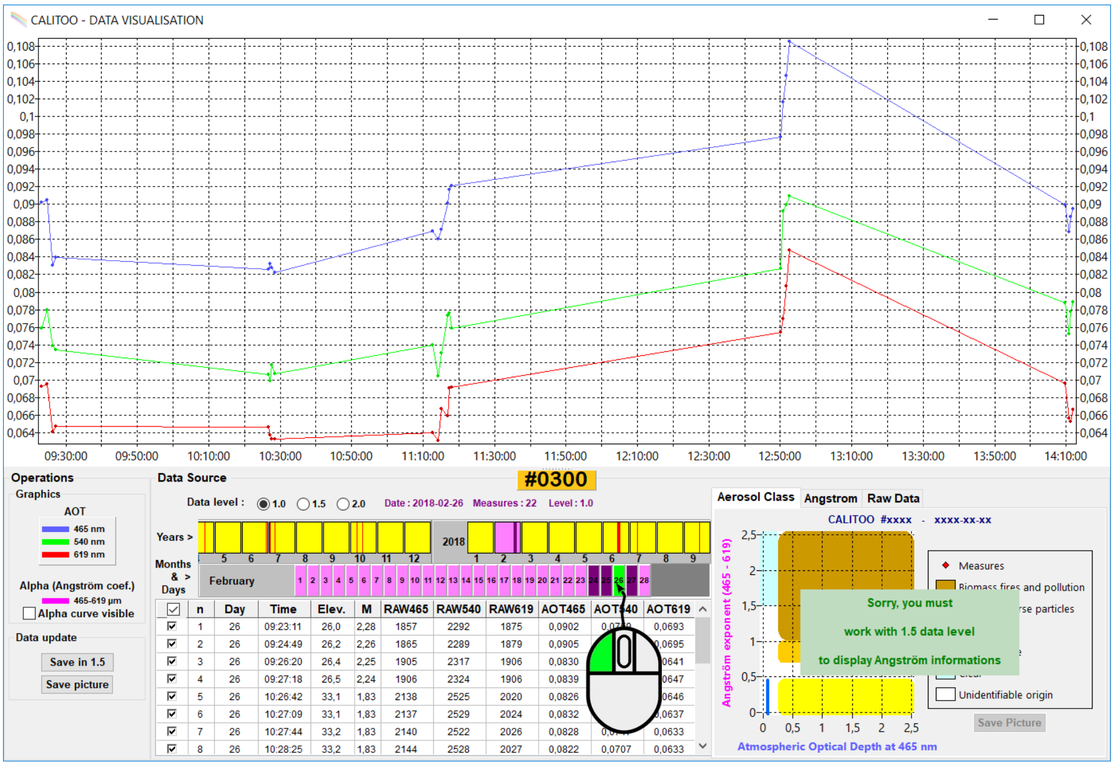


The panel of months and years can be moved with the mouse.

Choose the year and month containing the data you want to work with by clicking on a yellow rectangle containing red bars :

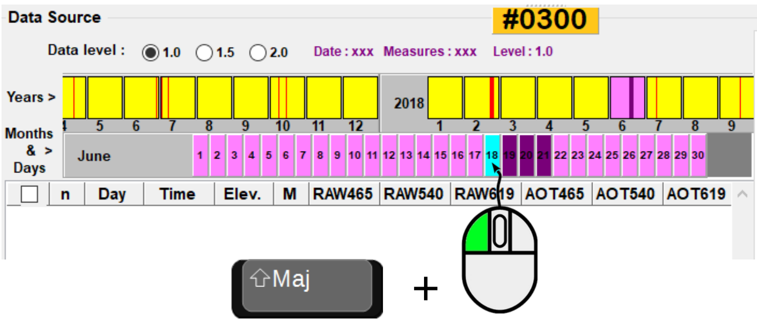


Select with the mouse and its left button, the day containing data (purple button) in the lower part of the calendar :

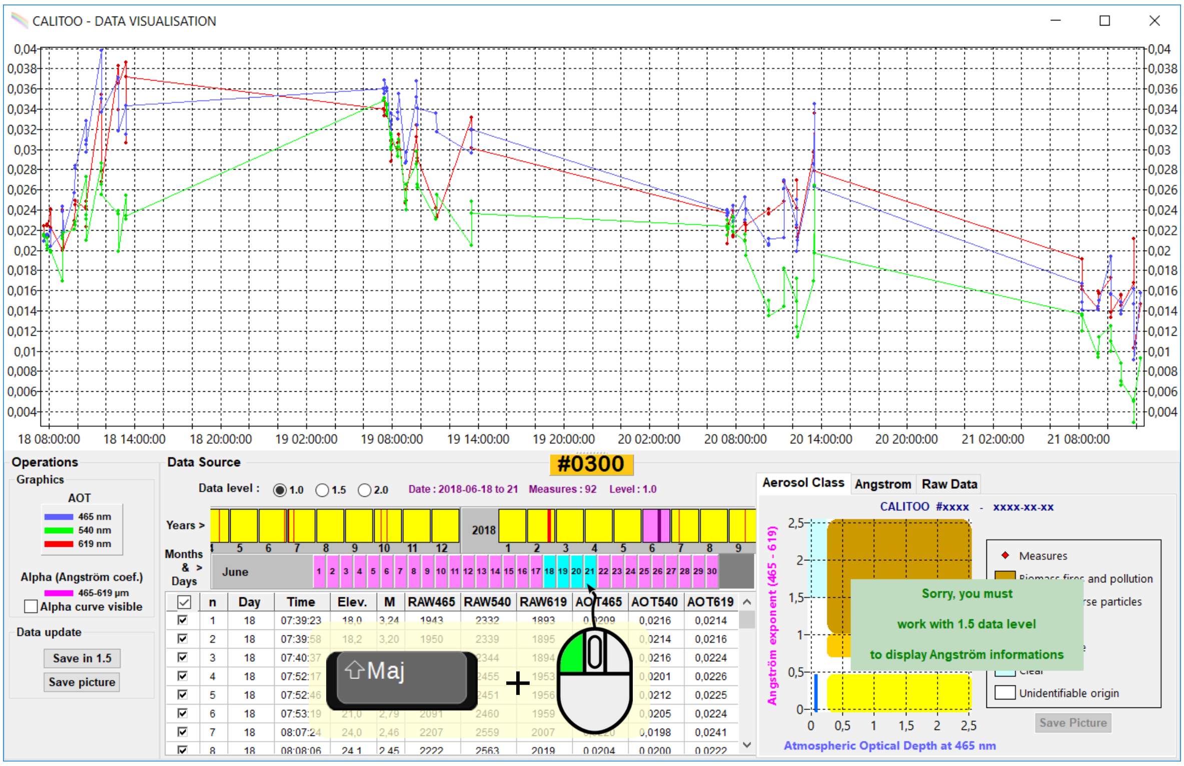


The data is immediately displayed at once in the data table, the data text viewer (Raw Data tab) and curves drawing.

You can view the data of several days : one must press Shift while clicking the first and last day of the selected interval.



Note that day boxes are colored in light blue



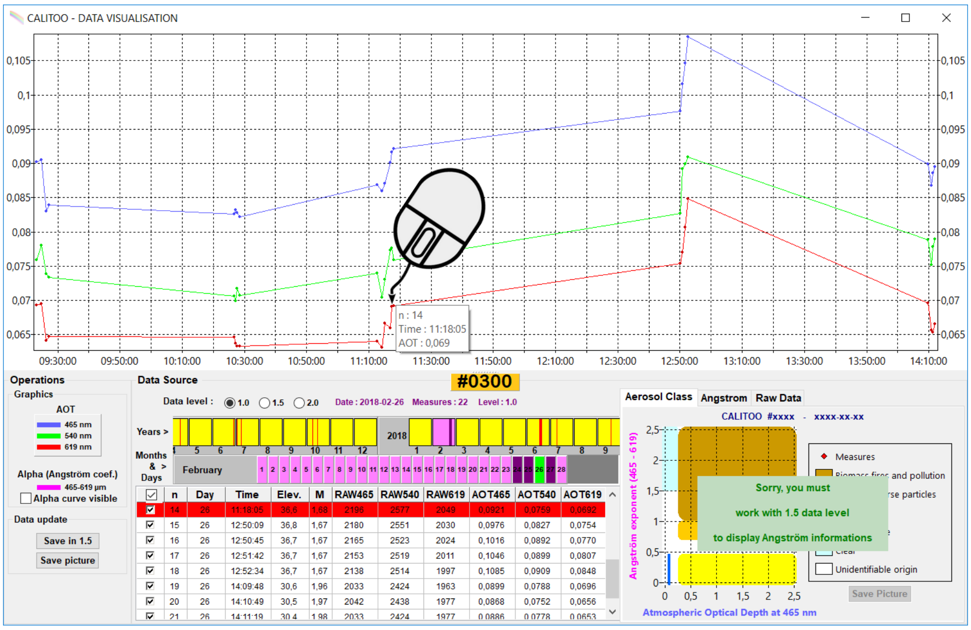
3.1.3 Manual data filtering

The manual filtering remove wrong data in your scientific user eyes.

For example, applying the rule: "The best measure is the one that gives the lowest optical thickness," to a group of three measures taken following, you will keep the point of the lowest value.

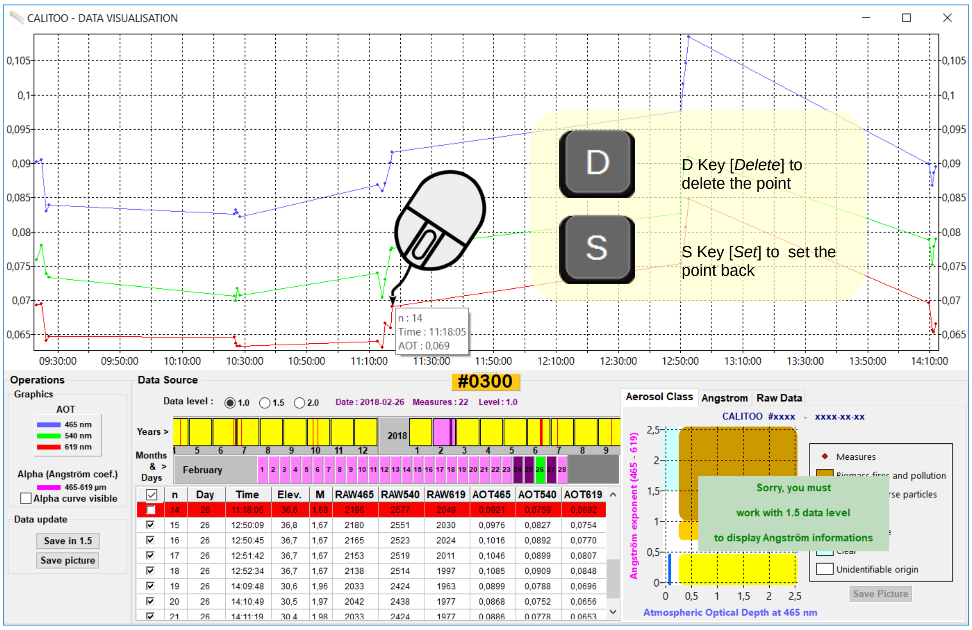
How to delete point ?

You move the mouse pointer over a curve point : the line of the corresponding data in the table is highlighted by the appropriate color.



Raw data taken 28 February 2018

Simply uncheck the line or press the[D] key to delete the curve data (point n=14) :



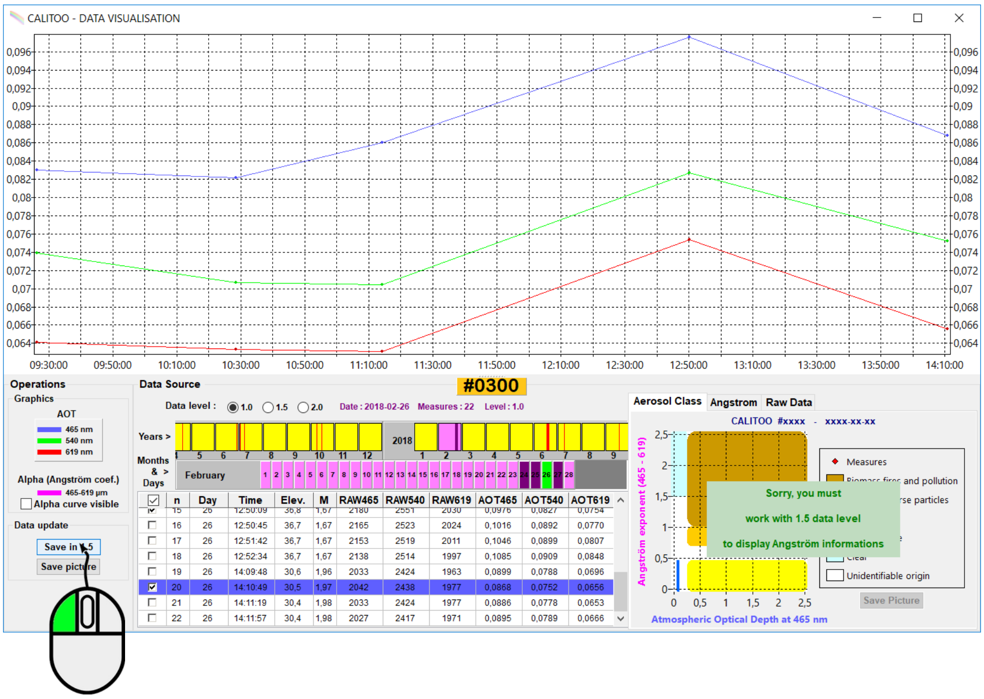
Data filtering in progress

Pressing the[S] key or re-checking the line restores the measurement.

Other reasons may cause you to delete data :

- AOT too fast variations may indicate the passage of a light veil over the sun: it should eliminate AOT higher values (smoothing the top) of a group in the time measurements .

- Very hight AOT values. We estimate that more than 0.5, the optical thickness is too hight to be only caused by aerosols and the role of atmospheric haze is not negligible .



When the job is finished, the processed data should be saved by clicking the [Save in 1.5] button. The data is now type 1.5 and stored in the appropriate folder.

See Appendix 4.7 for file descriptions.

3.1.4 Size particles determination

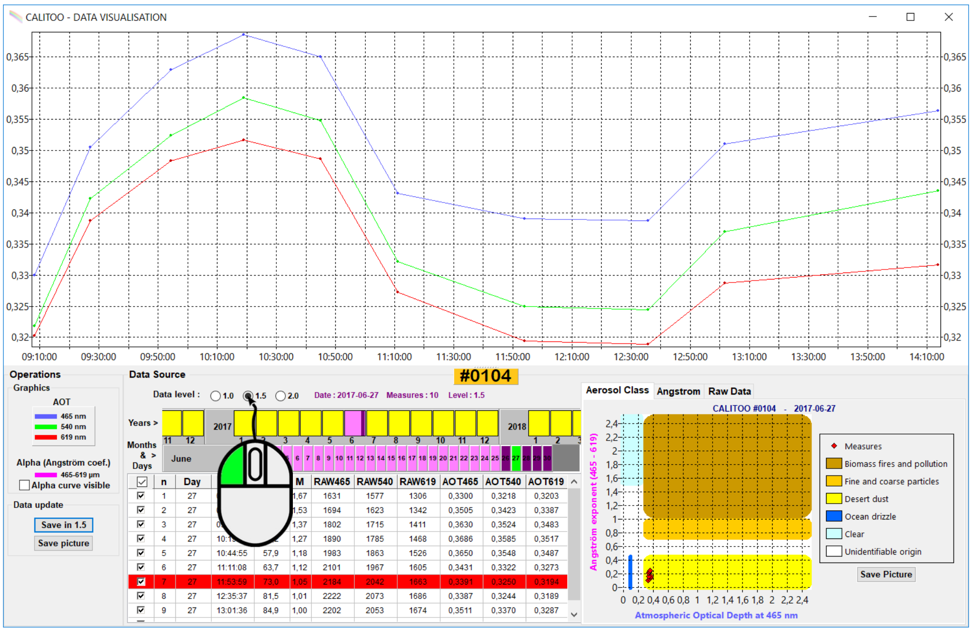
When atmospheric conditions are particularly stable and good measurements have been made, it is possible to determine the nature of the aerosols present mainly in the atmosphere.

Be careful, this is not always the case, even with good measurements, when there is no aerosol in the atmosphere, it is impossible to determine their size..

Angstrom coefficient

The Angstrom coefficient noted Alpha, makes possible to determine the size range of the measured aerosols. The computation of alpha is described in Appendix 4.2,

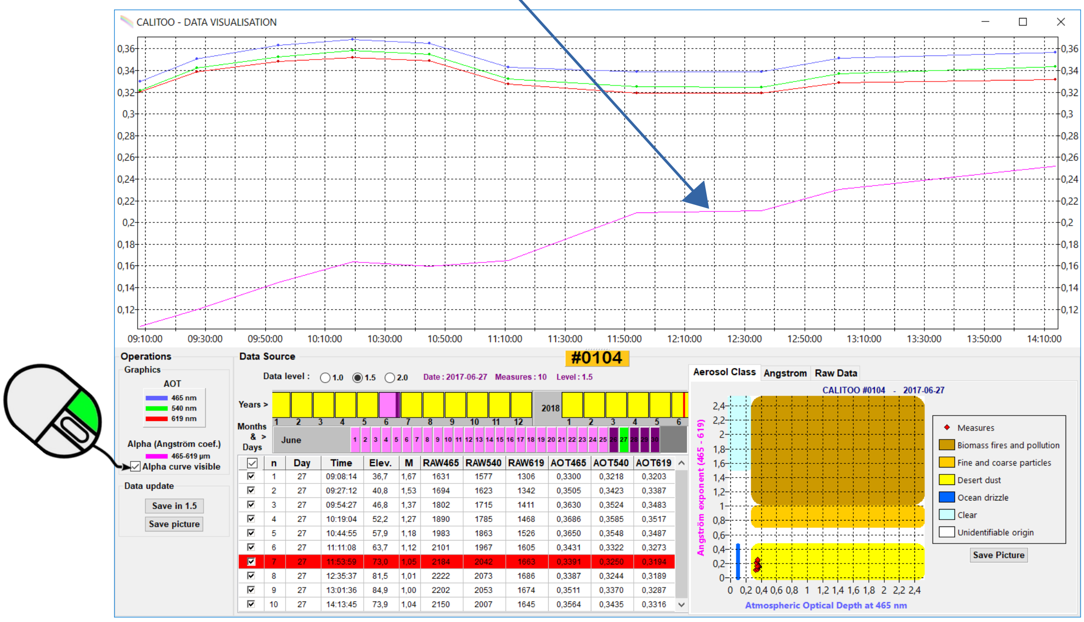
To start the calculations, you must work with **level 1.5** data by selecting the radio button :



I

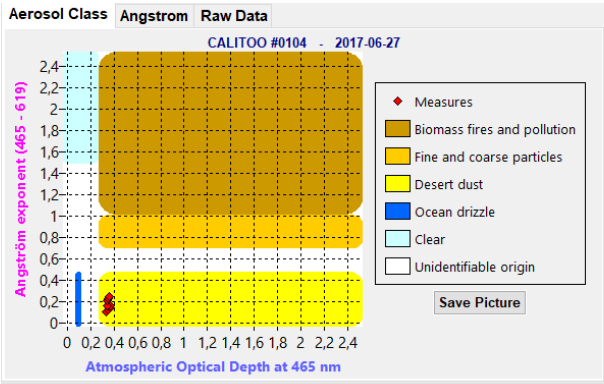
n *Level 1.5*, Aerosol Class tab and Angstrom checkbox (left) are enabled.

The curve representing the Alpha parameter is visible by selecting the Alpha curve visible checkbox :

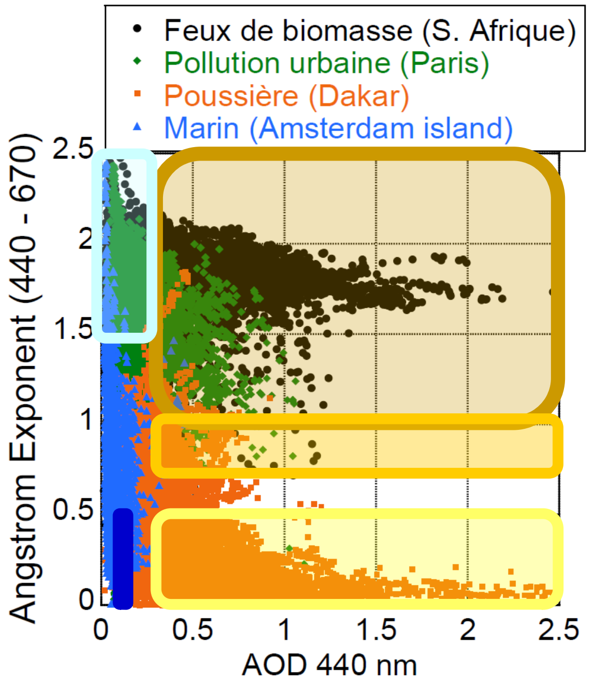


Aerosol Class tab

The software automatically calculates and places the red diamonds related to the measurements on the diagram to help us identify the nature and origin of the detected aerosols.



This diagram was built by the “Laboratoire d’Optique Atmospherique” (LOA) Lille, France, from these data :



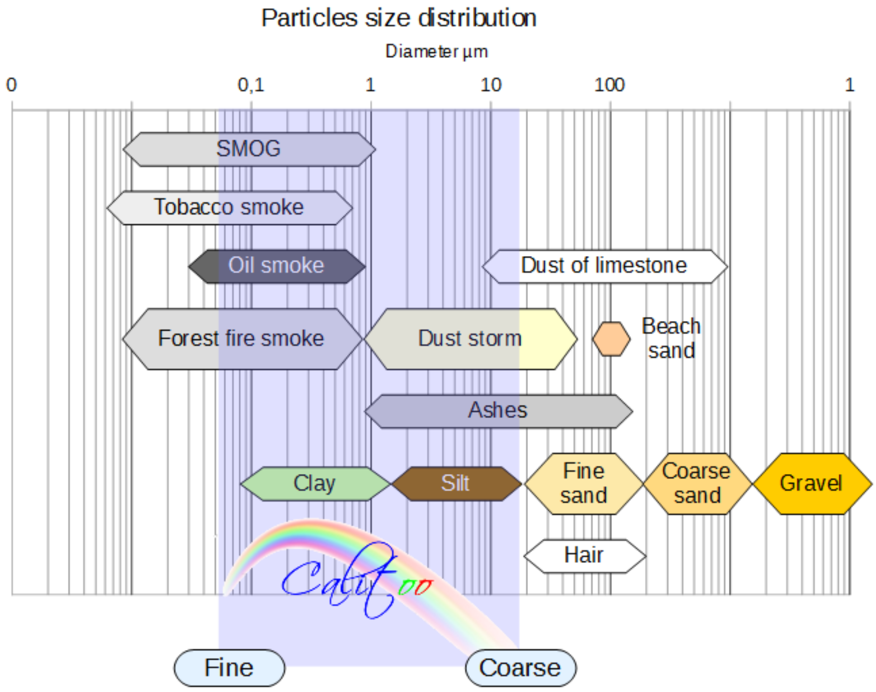
Sources Y Derimian LOA 2016

Calitoo detection range

The small (Fine) aerosols are similar to smoke and those of large size (Coarse) are of the "dust" type.

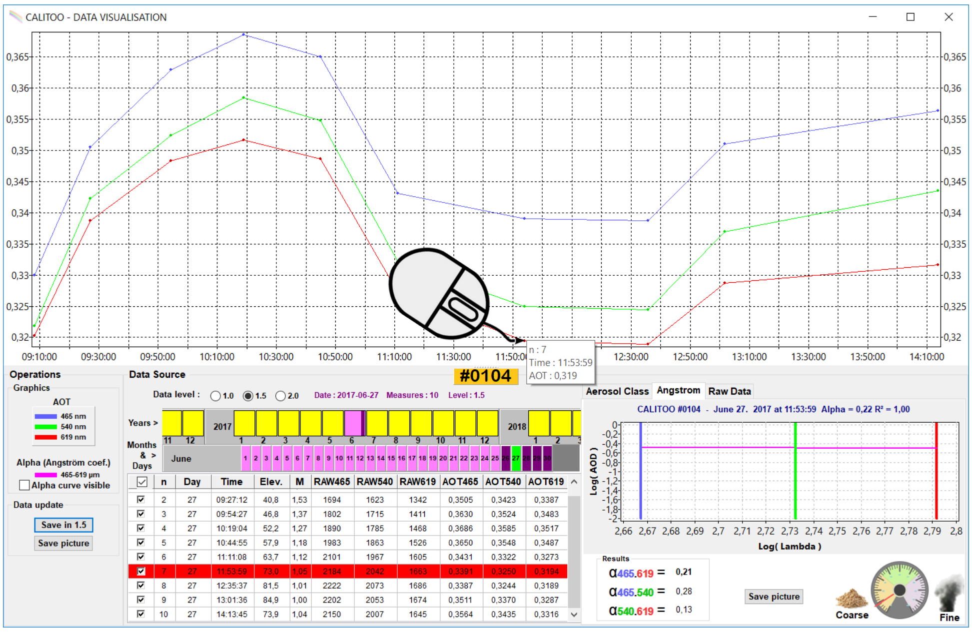
Under good conditions, the Calitoo is able to differentiate between forest fire smoke and Sahara sand brought by the wind over Europe, for example.

Its particle detection range is between 0.06 µm and 20 µm :

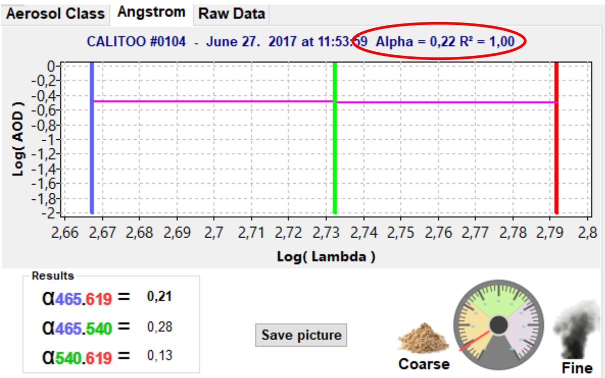


***Angstrom* tab**

By moving the mouse over a measurement point on the graph, the Angstrom tab allows you to view the Alpha coefficient.



Mathematically, Alpha is the steering coefficient of the slope of the straight line formed by the decimal logarithms of the AOTs as decimal logarithms of their wavelength.



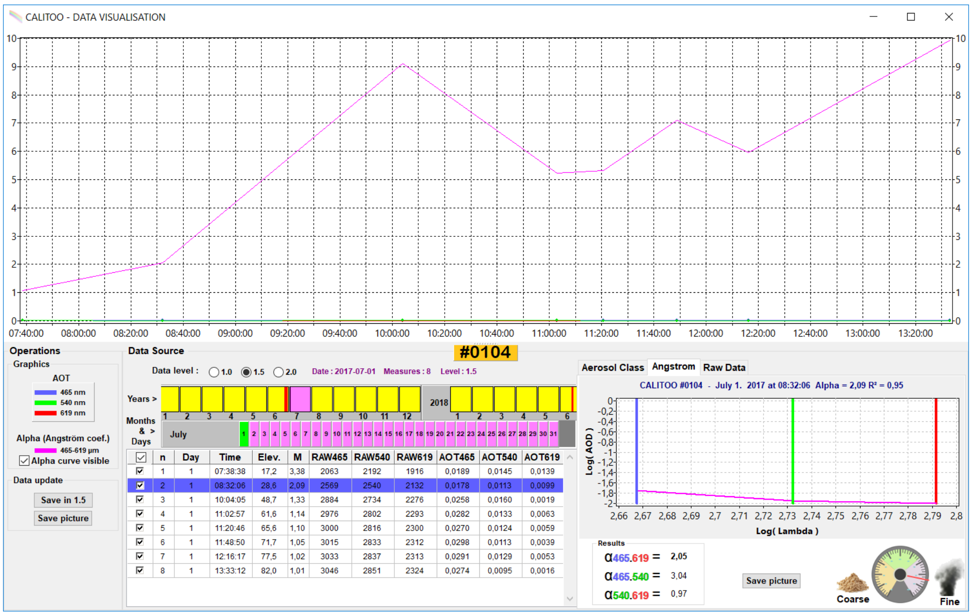
Be careful, interpretation of results is tricky. There are several signs to take into account to validate what you measure.

1 / The coefficient of Angstrom varies very little in one day.

2 / The correlation coefficient R² is an indicator of the coherence of a measure. If it is less than 0.95, the results must be considered unreliable.

Here are some examples :

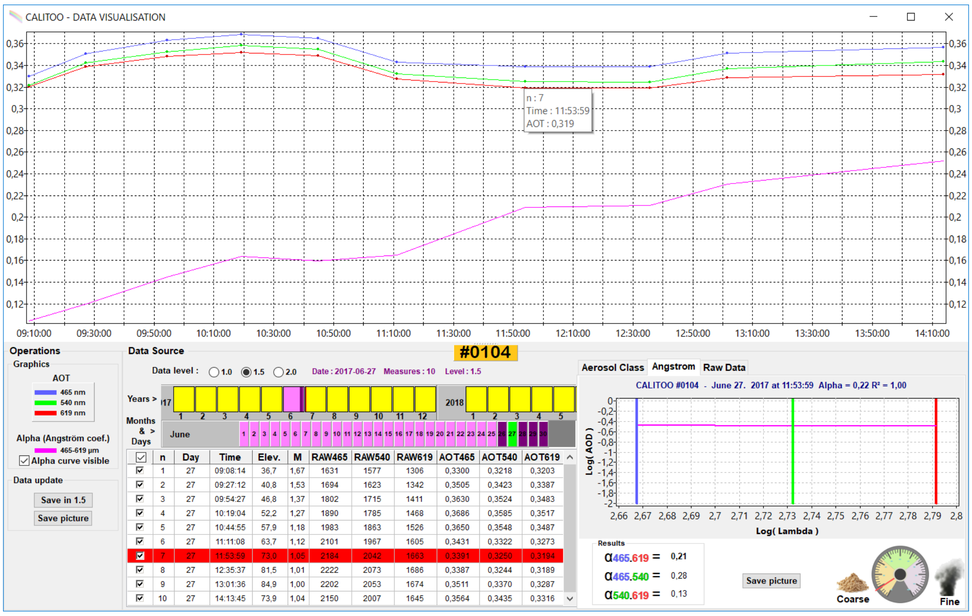
1st July 2017 measurements



Here we have a rapid variation of the Alpha probably caused by the appearance of a thin cloudy veil whose origin can come from aircraft drag. A variation of the Alpha in a day of 9 is huge!

The R^2 of the points of the day oscillate between 1 and 0.81, which confirms the impossibility of interpreting these results.

27 June 2017 measurements



In this case, Alpha varies from 0.15 in 6 hours and the R^2 are all close to 1.

The interpretation of the results can be taken into account. It will be possible to check on websites the presence of particles in the atmosphere of the observation site :

Dust forecast (University of Athens)

Global Aerosol forecasts

Sometimes, when the AOTs are very low, there may not be any particles in the air (yes, it does!). So Alpha's interpretation is not possible.

3.2 Data monitoring

The monitoring tool perform autocratically real-time measurements. You can choose data acquisition rate.

Results are displayed by curve drawings and text numbers.

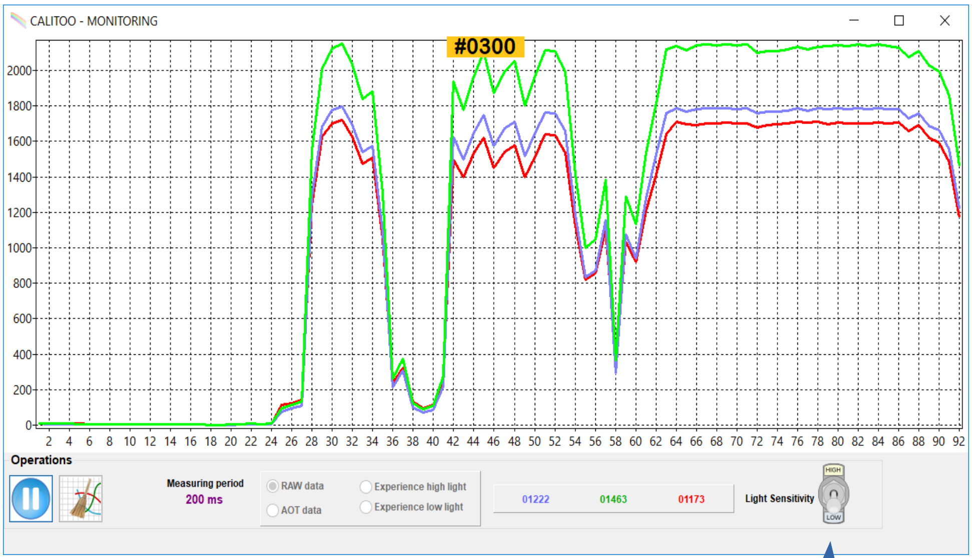
3.2.1 Raw data monitoring

We use this mode to find optical alignment with the Sun and so place the target circle in good position for each Calitoo device.

We enable you this tool because it can be used to guide an automatic system mounted on motorized platform, by example.

Photometer take measurements up to 5 data per seconds.

To start measurements, click on blue button at the top left of the monitoring screen.

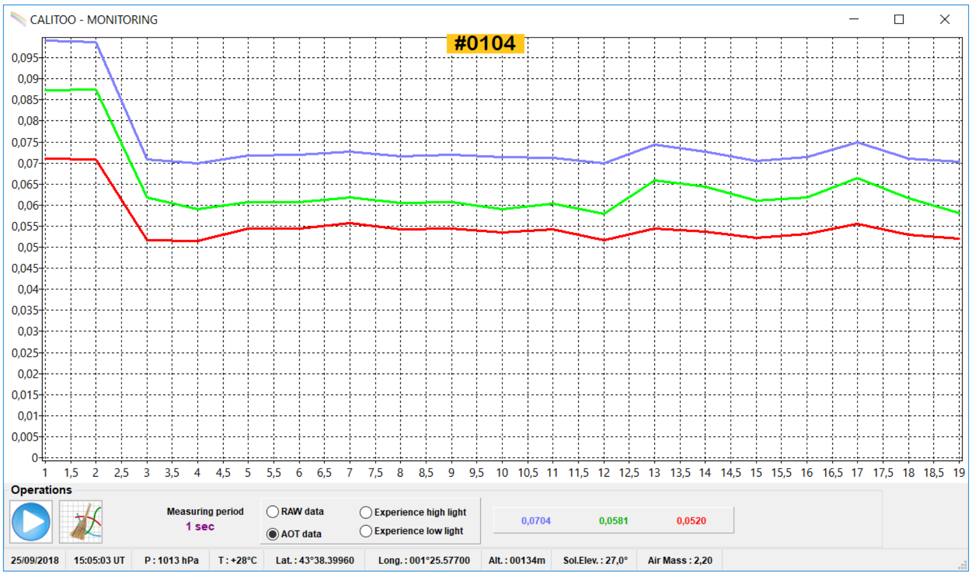


Raw measurements monitoring

Avoid pointing at the Sun if you have switched the Light Sensitivity switch to High.

3.2.2 Experimenting AOT monitoring

In the same way, it is possible to visualize in real time the optical thickness curves (AOT). To do this, the Calitoo must be able to receive GPS signals (outside or inside near a window), and aim stably at the Sun.



The data is refreshed every second and displayed in the lower right (AOT) and the AOT calculation parameters are displayed in the status bar at the bottom of the window (date, time, pressure, temperature, latitude, longitude, altitude, solar elevation and air mass).

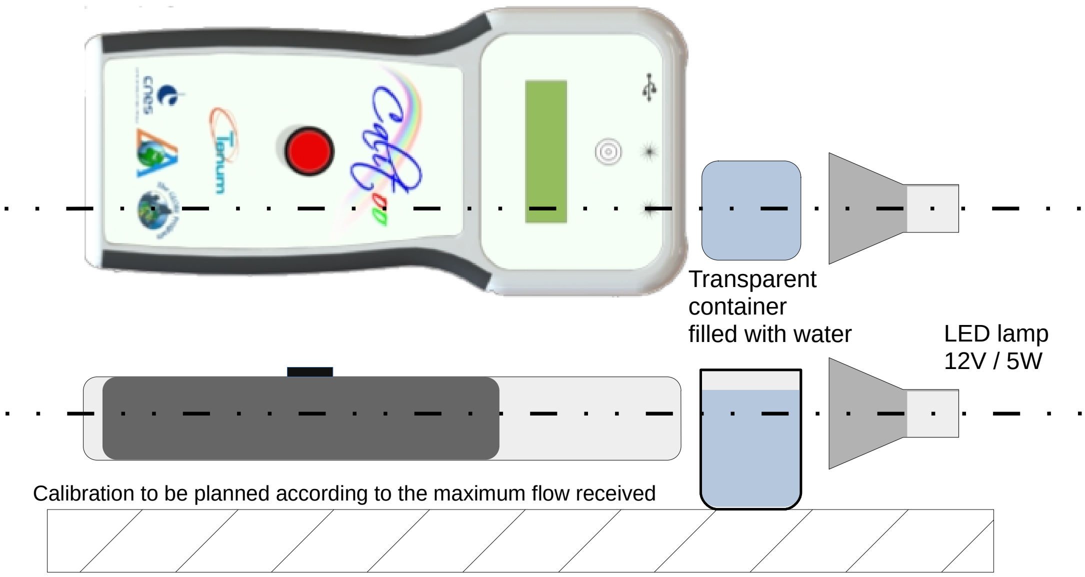
3.2.3 Particle size experimentation

Experimental understanding is important in the study of aerosols.

Aerosols can be modeled using particles present in the water that have a similar behaviour to those present in the air.

The use of water makes it possible to keep the particles in suspension for longer, to stay in a restricted area (aquarium) and does not require an enormous volume (about ten centilitres). Finally, the experimenter can easily change the type of particle to be observed.

Here is a typical assembly diagram that uses a 12 Volt LED lamp and a device that allows the Calitoo to be aligned with the lamp while leaving a space to place the container containing the water :



Web link to the video that explains the progress of the experiment

Calitoo video experiment

Some tips for your assembly:

- Use clean, smooth and transparent containers.

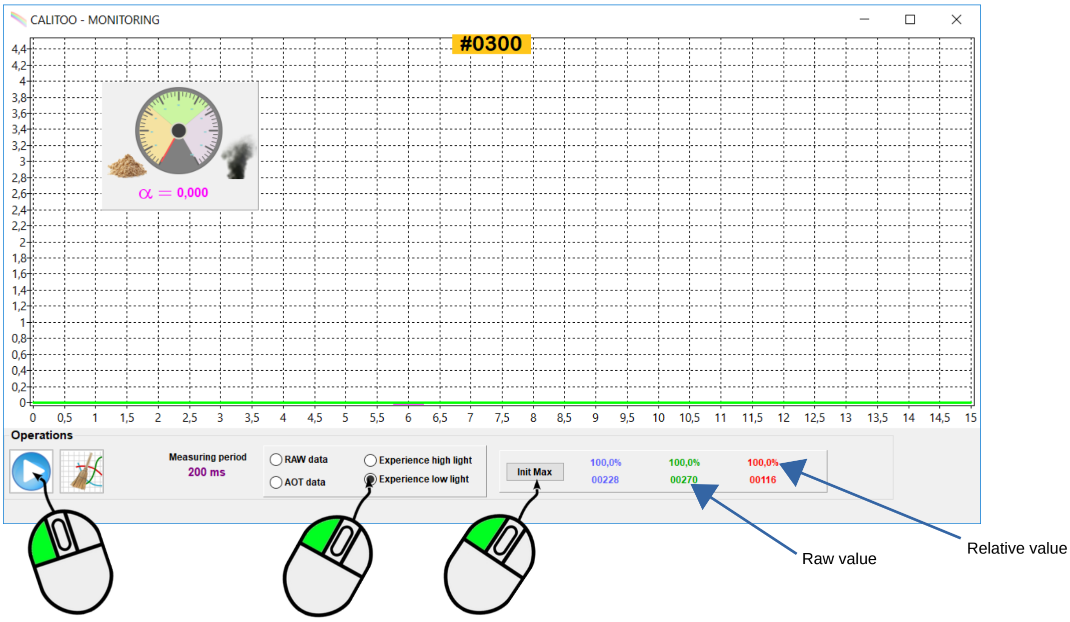
- Leave a space of about 5mm between the lamp and the transparent container to avoid any risk of overheating. No more so as not to lack luminous flux.

- Adjust the position of the Calitoo with the lamp using the "Monitoring of raw values" function seen in 3.2.1 and validate your photometer calibration when the maximum raw values are reached.

- Make a solid and stable cushion.

Initiating measurements

The first step in the simulation is to measure the reference level. This is the equivalent of an aerosol-free atmosphere and therefore measures the luminous flux through a container filled with pure water.



With the monitoring module, select ● Experience low light then to start the measurements, click on the blue round button on the left.

Place the container of pure water and turn on the light.

Click on the[Init Max] button to initialize and obtain the reference level,

In the rest of the experiment, we will add elements to the water in the container. We advise you to prepare several containers which will allow you to distinguish between the different elements.

Let's start by simulating the small particles :

Simulation of small particles

We will use milk to simulate the small particles (smoke type) in the water container.

Results of measurements with milk: The Angstrom coefficient (Alpha) is high, which is the sign of the presence of most fine particles

Visually, the blue, green and red curves are <u>spaced</u> from each other.

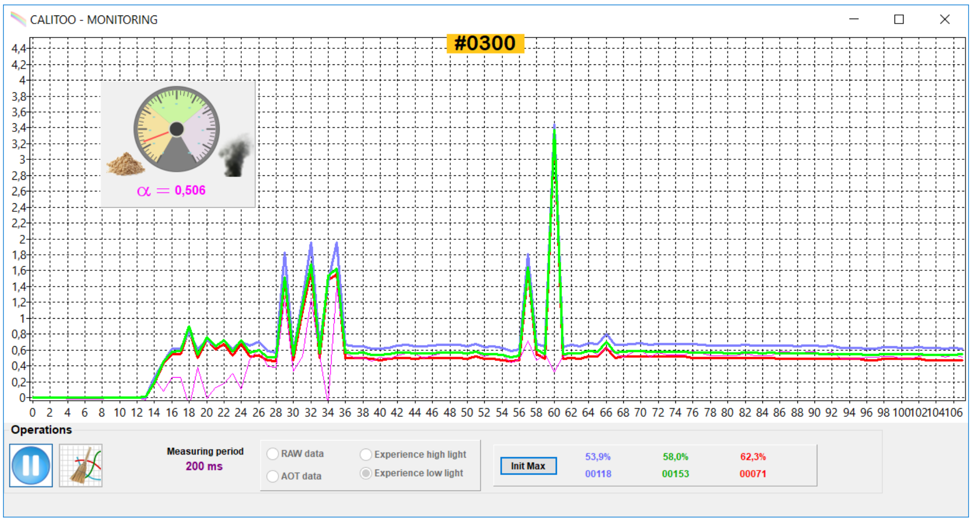
Results of measurements with milk:

- The particle gauge needle is pointing well towards the smoke cloud, indicating the detection of fine particles.

- The Angstrom coefficient (Alpha) is high, which is the sign of the presence of a majority of fine particles.

Simulation of coarse particles

In another clean container, pour water, repeat the initialization procedure ([Init Max] button) and add white clay or flour in small doses to observe the evolution of the measurements. Be careful, Too much clay will eventually weaken the luminous flux too much and particle detection will not be possible.



Visually, the blue, green and red curves are tight.

Results of measurements with flour:

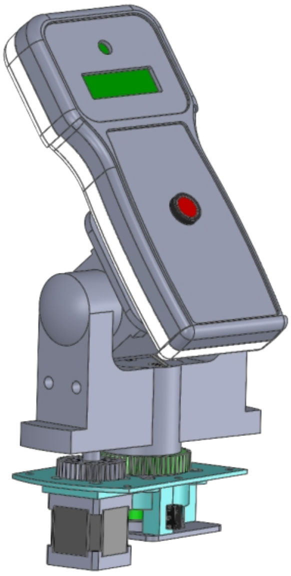
- The needle on the particle gauge is pointing well towards the sand pile, which indicates the detection of large particles.

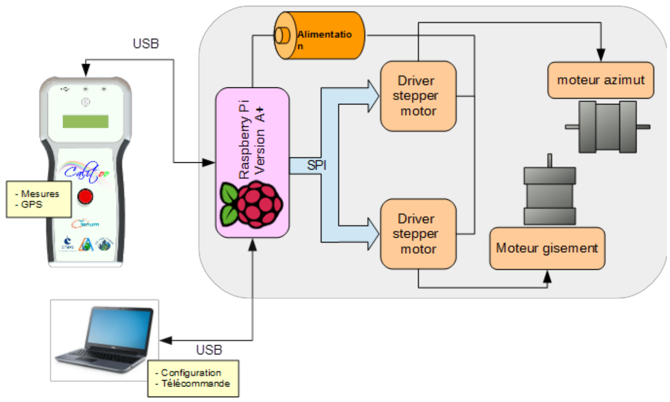
- The Angstrom coefficient (Alpha) is low, which is a sign of the presence of large particles.

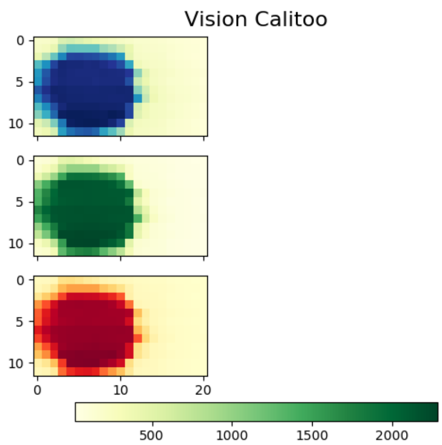
Other possible project :

Automatically measure continuously in the manner of the photometers of the Aeronet network : a motorized device to point the Sun before each measurement.

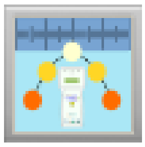
It is therefore fairly easy to make an aerosol profile for a full day.







3.3 Langley calibration



3.3.1 Principle

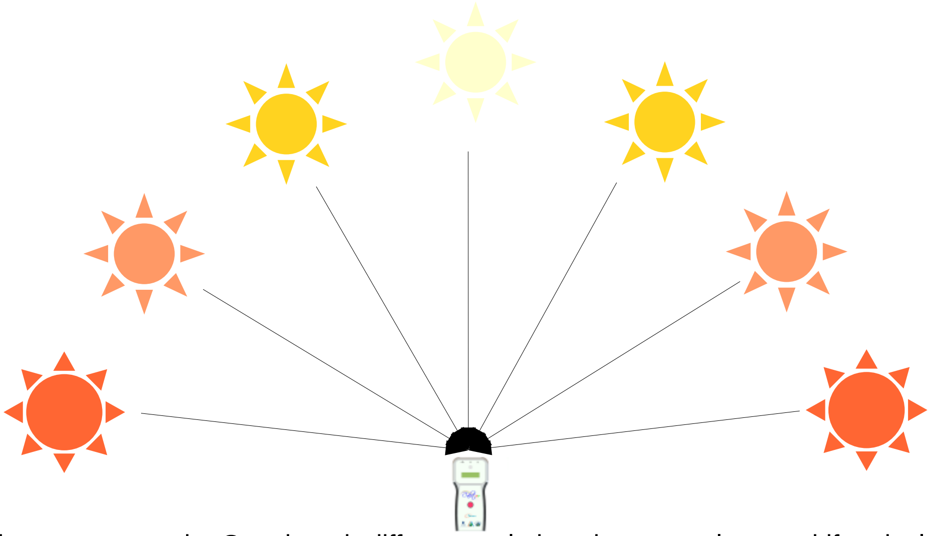
The photometer calibration consist to determine by measurements and calculs, the light raw value given by a device at the atmosphere top, in a precise lengthwave.

In the case of the Calitoo, calibration coefficients are binary numbers and named CN_0 (Numérique zéro). We have CN_0_465 for the blue, CN_0_540 for the green and CN_0_619 for the red.

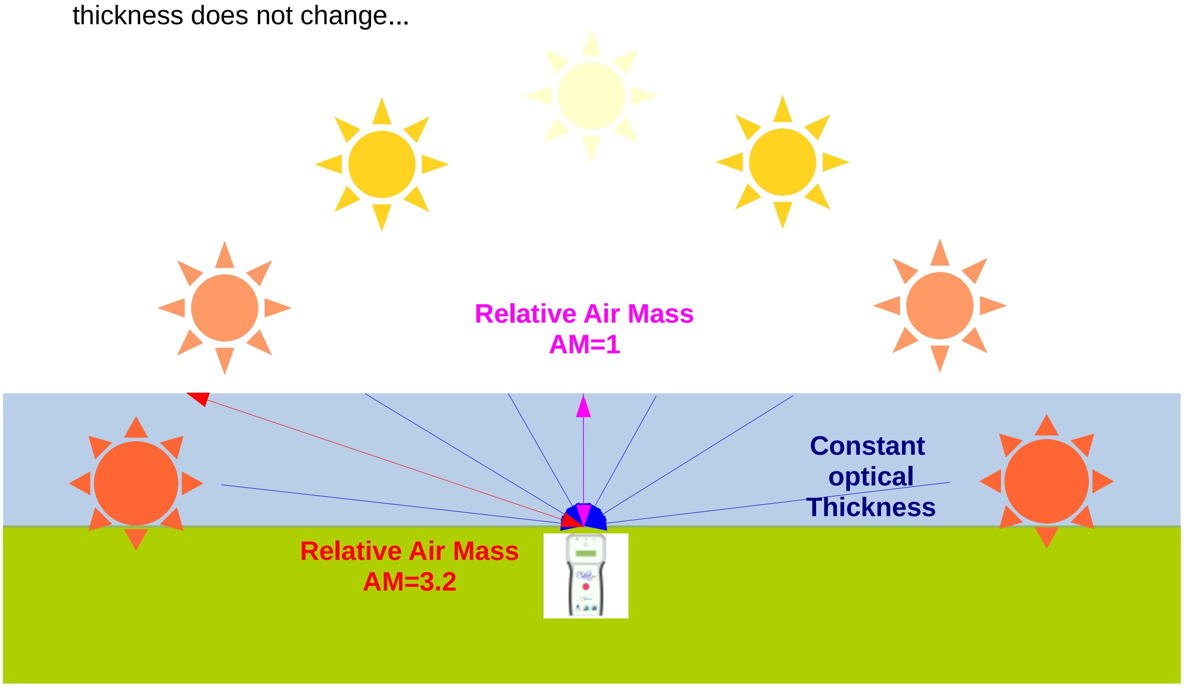
3.3.2 Method

Langley method consist to take light measurement with differents atmospheric thickness

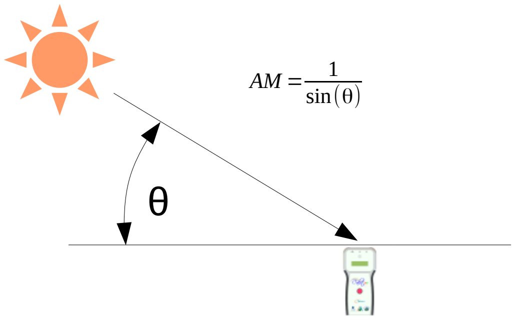
Otherwise, optical thickness must not change. You have to take measurements by calm and stable weather.

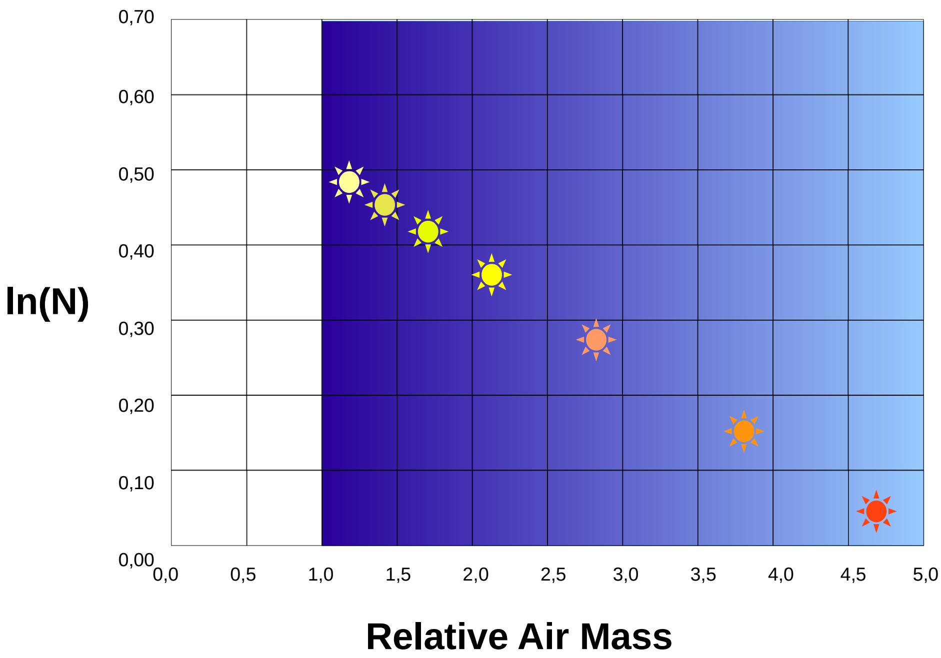


If photometer sea the Sun though differents relative air mass values and if optical thickness does not change...

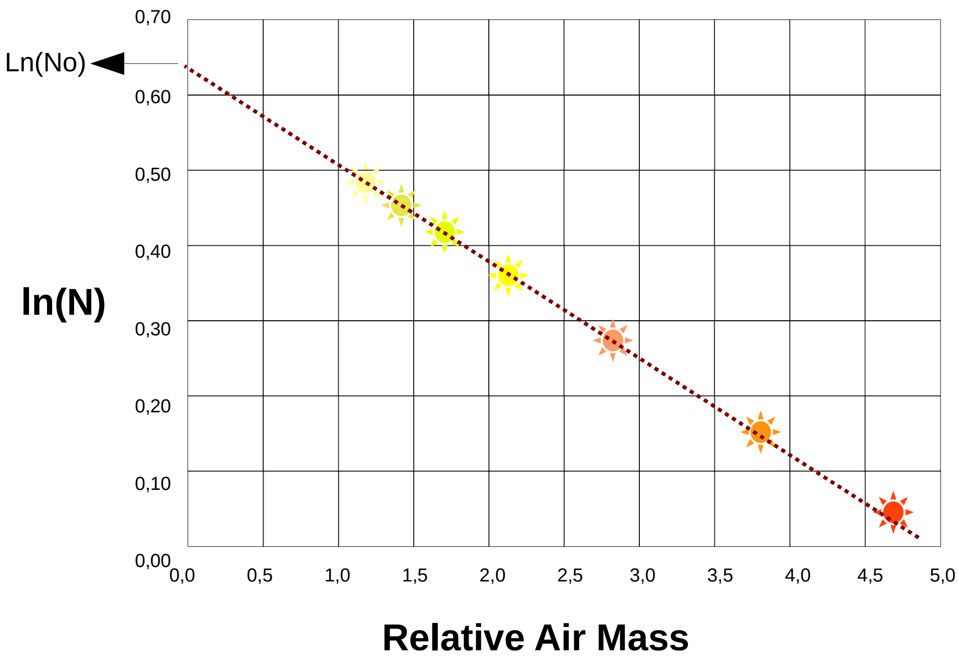


...then, the measurement logarithm is proportional to relative air mass (AM)





By fitting a line through the data (linear regression), the intersection of said line with the y-axis, where m = 0, is the logarithm of the measurement that the instrument would produce if it were no atmosphere Ln (No).



3.3.3 How to do ?

To perform a Langley type calibration, choose a day of good and stable weather to have a constant optical thickness throughout the day. That is to say, a clear sky without clouds above sea level, without wind.

The sites in altitude, away from cities offer more easily this type of sky. We must stay on the same site for all measurements.

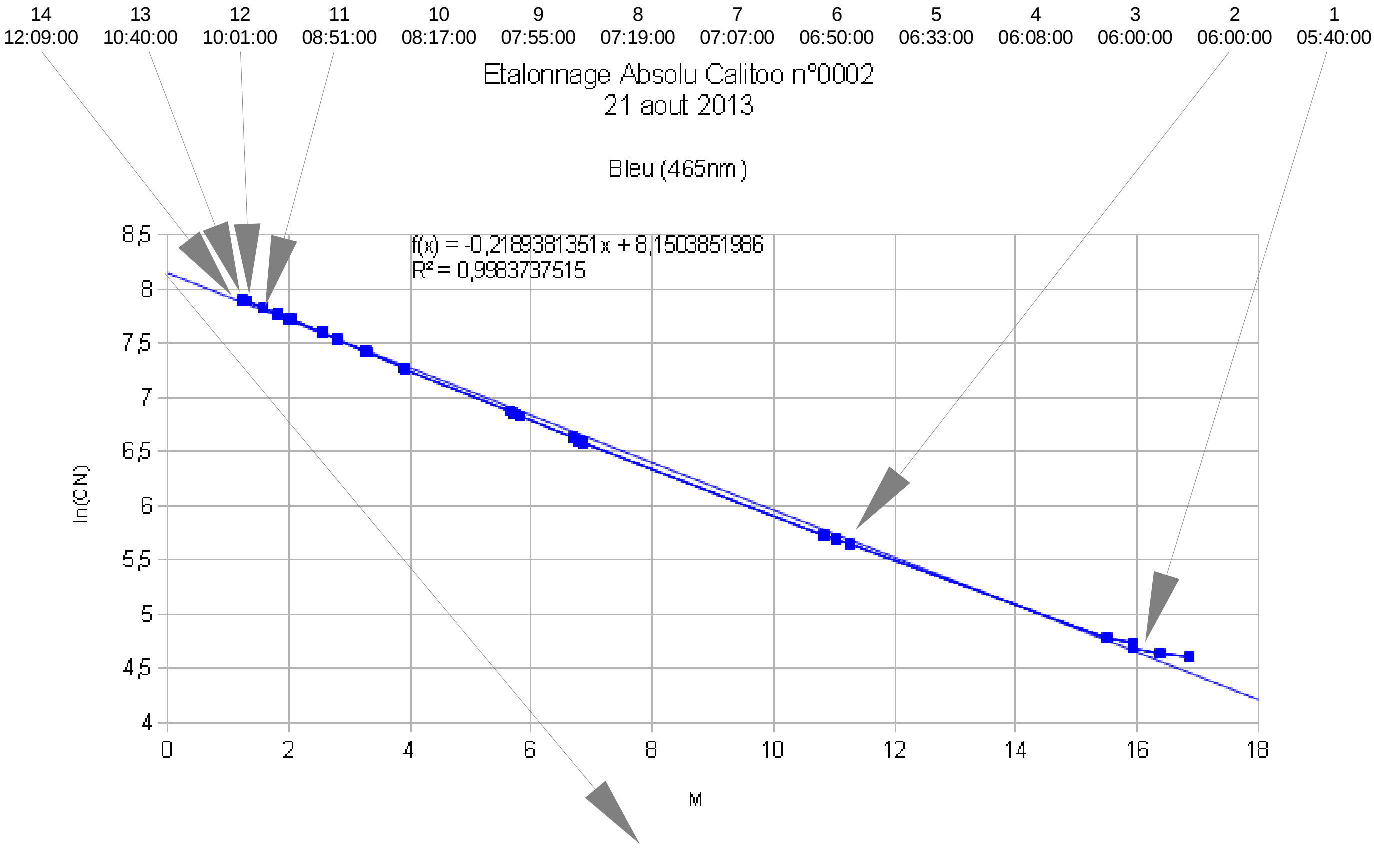
So take action one or two hours after sunrise until solar noon least the place. (Red Sun is going to pale yellow Sun on the previous graph).

Continuing the afternoon, we get the "down" curve, which theoretically merges with the "rising" curve. This can be a weather stability index of the day.

It is not recommended to perform calibrations during winter because the sun is low on the horizon, the air mass is not enough to approach 1 (over 2.5 on the winter solstice so that it reaches 1.07 at the summer solstice for example in Toulouse, in the south of France).

During the measuring morning of measurements, you should take at least five series from 3 to 5 measurements.

Here are measurements taken August 21, 2013 near Toulouse in blue color. The data were gathered in a spreadsheet and the equation of the trend line has been displayed, allowing us to calculate the CN_0 parameter.



$CN_0\_465 = \exp(8,1503851986) \Rightarrow CN_0\_465 = 3465$

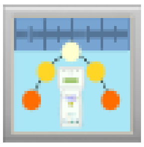
3.3.4 Calibration with software

The PC software for managing the Calitoo has a Langley calibration tool. We will illustrate its handling by an example :

The photometer Calitoo No. 30 has been used Tuesday, February 4th, 2014 to take several sets of measures in order to achieve Langley calibration.

The first step written on page 13, allows you to download photometers data on your computer.

Then you go to the Tools tab and click on the icon "Langley calibration".



The windows LANGLEY Calibration opens and look like this :

The window consists of three areas:

- The Data Curves area displays the measurement points and the approximation straight lines. You can enlarge them for better reading by double clicking it. The same action makes them resume their original size. .

- The Parameters panel displays the numerical values of the initial calibration coefficients and new coefficients calculated in real time and correlation coefficients (Deviation between the measurements curve and the straight line of approximation. The closer it is to 1 , is the best approximation) .

The Photometer update allows :

- update directly in the connected photometer, the three coefficients CN_0 with new values.

- create a calibration report in PDF format (that is the one that comes printed in the box of your instrument) .

- The Data Source panel allows you to retrieve data according to the day, month and year to which they were taken. We start by detailing the area which is the first task to proceed calibration .

3.3.5 Data Source

Data are displayed as a calendar showing the years, months and days.

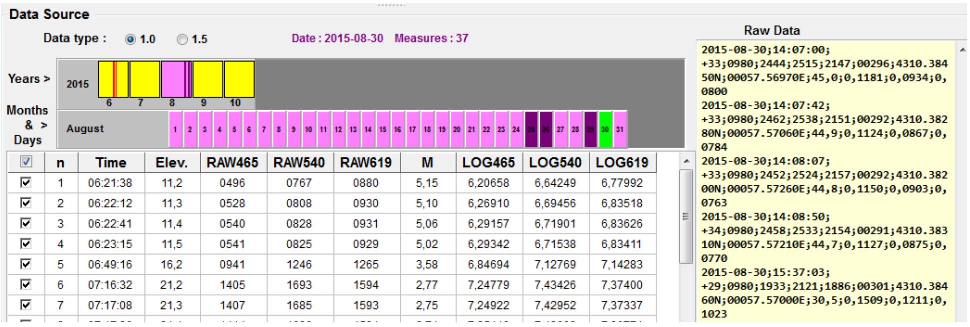
Day for which measures have been taken are displayed as red bars on the yellow background of the month. The calendar starts with the photometer manufacture date and ends the month of the current date.

Here the photometer was manufactured in November 2013 and measurements at the beginning of February 2014.

Clicking the yellow rectangle in the month of February 2014 refines research data :

We see that the available data correspond to measurements made on February 4th and 5th 2014.

We will click on February 4th to see these measurements :



Data are immediately loaded, displayed and processed.

Some details on the Data Source area :

The purple text in the window displays the date when data were taken and the number of measurements used in the calculation. We will see below how to use these data.

Raw data can be seen, as they have been downloaded from the memory of the photometer, in the yellow section on the right side of the window.

The table presents the measurements in rows in chronological order of implementation.

n : Order of measurement

Time : Time of measurement

Elev : Solar elevation (angle between the ground and the Sun) in degrees.

RAW465, **RAW540** and **RAW619** : Raw measurement values in three wavelengths.

M : Calculated air mass (see page 18)

LOG465, **LOG540** and **LOG619** : natural logarithms of raw measurements.

Selecting data

You can choose to use or not, a measure for the calculation of calibration coefficients.

To remove a measurement from calculation set, you have to uncheck the box at the start of the line in the table. After this action, all calculations are redone, the curves are traced and the number of measurements used (purple text) is decremented.

The objective is to use the best measures to improve the quality of the calculated coefficients.

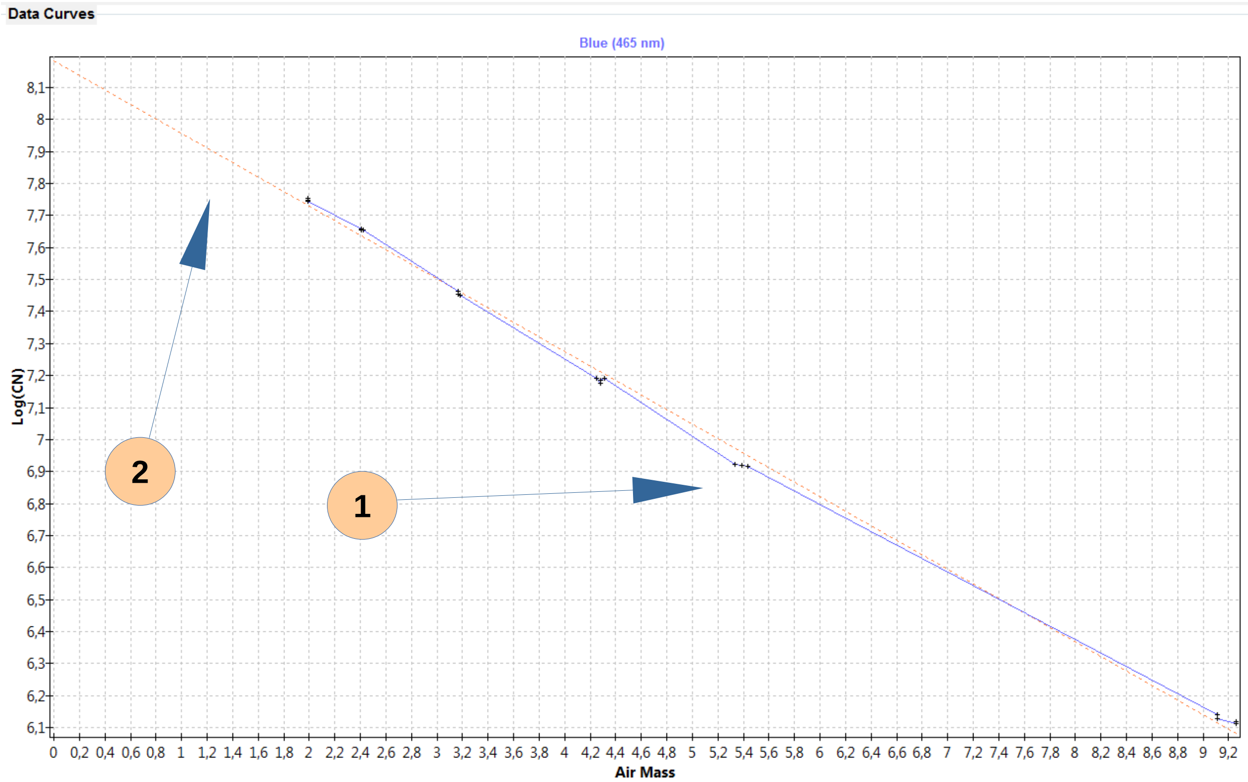
You have to :

- Monitor the correlation coefficients that must come as close as possible to 1.

- Use a minimum of 5 different sets of measurements

3.3.6 Measurements curves

For each wavelength, two curves are drawn :

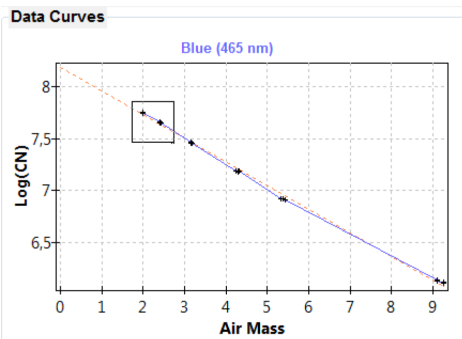


1- The curve connects calculated points (log). Points are shown as small black crosses

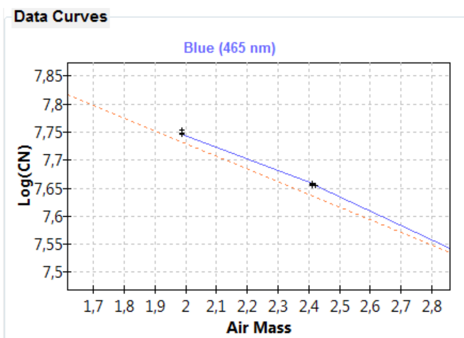
2- Approximation straight line (in dotted lines) whose intersection with the y-axis will display the CN_0.

You can view the curve in a larger format by double-clicking on it, as in our example.

Zooming is also possible by enclosing with the mouse button pressed the party to zoom. Operation to the top left point to the bottom right under (1) and release the mouse button: zoom is performed (2).



(1)



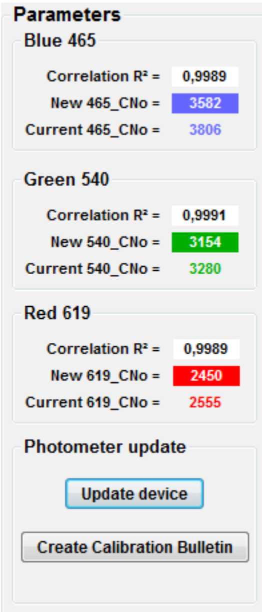
(2)

To un-zoom, doing the same operation but from the lower right to upper left.

Before trying to publish a calibration bulletin, make sure that the curves have a presentable scientifically. We recommend that you leave the three curves on the same scale in order to have a coherent set when publishing..

3.3.7 The calibration parameters

For each wavelength, the current calibration parameter is displayed as the new parameter calculated. This will allow you to assess the new calibration in the comparison. Too much difference between these values may be a sign of a problem for your photometer (clogged or dirty sensor).



The three decimal correlation coefficient used to assess the consistency of the measurements for calibration. A good calibration should have a ratio above 0.99, absolutely 1.

Updating coefficients

The "Update device" button to transmit the USB link the new coefficients connected to the photometer.

Calibration bulletin publication

Once satisfied with your work, you must create the calibration bulletin will file two forms: a text file and a PDF file that are described in the following paragraph..

WARNING ! CREATE BULLETIN CALIBRATION DOES NOT AUTOMATICALLY UPDATE THE FACTORS CALIBRATION PHOTOMETER !

3.3.8 Organization on the hard disk

For the photometer identified No xxxx, when the user chooses to produce a calibration report, data is written to the file :

```
<username>/CalitooData/xxxx/xxxx_CALIBRATION/xxxx_LANGLEY/
```

A text file and a PDF file is produced.

Example content file : CAL0030_20140204_LAN.txt

```
LANGLEY CALIBRATION METHOD
CALITOO #0030
--------------------
Date : 2014-02-04
Latitude : 43°38.38540N
Longitude: 001°25.59330E
Altitude : 00104M
Used Data: 26
--------------------
CN0_465=3582
CN0_540=3154
CN0_619=2450
--------------------
R²_465=0.9989
R²_540=0.9991
R²_619=0.9989
------------------------------------------
Used;n;Time;Elevation;RAW465;RAW540;RAW619;M;LOG465;LOG540;LOG619
1;1;07:49:48;06.2;0454;0711;0838;9.26;6.11810;6.56667;6.73102
1;2;07:50:06;06.2;0452;0711;0844;9.26;6.11368;6.56667;6.73815
1;3;07:50:23;06.3;0459;0719;0848;9.11;6.12905;6.57786;6.74288
1;4;07:50:33;06.3;0464;0722;0852;9.11;6.13988;6.58203;6.74759
1;5;08:18:47;10.6;1008;1268;1268;5.44;6.91572;7.14520;7.14520
1;6;08:19:05;10.7;1011;1268;1270;5.39;6.91870;7.14520;7.14677
1;7;08:19:23;10.7;1010;1274;1277;5.39;6.91771;7.14992;7.15227
1;8;08:19:42;10.8;1015;1274;1274;5.34;6.92264;7.14992;7.14992
1;9;08:38:04;13.4;1326;1543;1466;4.32;7.18992;7.34148;7.29029
1;10;08:38:21;13.5;1321;1544;1468;4.28;7.18614;7.34213;7.29166
1;11;08:38:39;13.5;1307;1536;1469;4.28;7.17549;7.33694;7.29234
1;12;08:38:53;13.6;1328;1544;1464;4.25;7.19143;7.34213;7.28893
1;13;09:14:30;18.3;1722;1857;1676;3.18;7.45124;7.52672;7.42417
1;14;09:14:48;18.4;1729;1869;1677;3.17;7.45530;7.53316;7.42476
1;15;09:15:04;18.4;1741;1873;1676;3.17;7.46221;7.53530;7.42417
1;16;09:15:29;18.4;1745;1879;1687;3.17;7.46451;7.53849;7.43071
1;17;10:09:44;24.4;2111;2160;1861;2.42;7.65492;7.67786;7.52887
1;18;10:09:58;24.5;2111;2151;1870;2.41;7.65492;7.67369;7.53369
1;19;10:10:20;24.5;2110;2149;1863;2.41;7.65444;7.67276;7.52994
1;20;10:10:38;24.5;2115;2158;1860;2.41;7.65681;7.67694;7.52833
1;21;10:10:54;24.5;2119;2152;1865;2.41;7.65870;7.67415;7.53102
1;22;11:58:52;30.2;2311;2294;1952;1.99;7.74544;7.73805;7.57661
1;23;11:59:09;30.2;2312;2312;1956;1.99;7.74587;7.74587;7.57866
1;24;11:59:28;30.2;2319;2307;1962;1.99;7.74889;7.74370;7.58172
1;25;11:59:46;30.2;2318;2298;1957;1.99;7.74846;7.73979;7.57917
1;26;12:00:08;30.2;2330;2315;1970;1.99;7.75362;7.74716;7.58579
0;27;13:38:40;26.6;2043;2052;1759;2.23;7.62217;7.62657;7.47250
```

The description of the data columns is identical to the table on Appendix 4.7.

In the first column, if the measurement line was used was a "1" if a "0". These indications are used for the calculation of calibration coefficients.

3.3.9 Log file

At each change of calibration parameters, the software updates a log file. It is located in the folder :

<*username*>/CalitooData/xxxx/xxxx_Log.txt

for our example and is called : **0030_Log.txt**

Here are its contents:

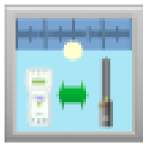
```
Calitoo #1302-0030
-------------

2013-12-14 13:14:32
-------------------------------------------------------------
CN0_465=3423;RAY_465=0.19490
CN0_540=3132;RAY_540=0.10637;OZ_540=0.0128
CN0_619=2455;RAY_619=0.06281;OZ_619=0.0154

2014-02-21 09:43:10
-------------------------------------------------------------
CN0_465=3582;RAY_465=0.19490
CN0_540=3154;RAY_540=0.10637;OZ_540=0.0128
CN0_619=2450;RAY_619=0.06281;OZ_619=0.0154
```

We see that the photometer No. 30 received the first calibration coefficients December 14th, 2013 and new coefficients, February 21th, 2014.

This log will track the evolution of each meter and will help to refine the accuracy of measurements.



3.4 Aeronet Intercalibration

3.4.1 Principle

The photometer calibration consist to determine by measurements and calculations, the light raw value given by a device at the atmosphere top, in a precise wavelength.

In the case of the Calitoo, calibration coefficients are binary numbers and named CN_0 (Count Numeric zero). We have CN_0_465 for the blue, CN_0_540 for the green and CN_0_619 for the red.

3.4.2 Method

The inter-calibration is a calibration method that uses data from reference photometer to compute AOT data that should measure the photometer to be calibrated. With these AOT and with a reverse calculation, we find the calibration coefficients (Cn_0) . Ideally, you should do both photometer measures at the same time and same place.

For now, one method of intercalibration is offered : AERONET intercalibration.

This method uses Aeronet network photometers as reference devices,. They are a world reference for measurements of aerosols.

The CALITOO intercalibration method witch will use a Calitoo photometer as etalon, is being validated and will be available in a future version of this software.

3.4.3 What is AERONET ?

The program AERONET (Aerosol RObotic NETwork) is a network of land aerosol measurements made by NASA and PHOTON (photometry for Operational Processing Standards satellite; Univ. De Lille 1, CNES and CNRS-INSU).

It is greatly expanded by the networks and employees of national agencies, institutes, universities, individual researchers and partners.

The program feeds an active database for the long term, into the public domain and easily accessible.

It includes the optical aerosol measurements, micro-physical and radiative properties of aerosols for research.

Participants in AERONET provide optical observations distributed globally, spectral depth of aerosols (AOD), the reversion products, the precipitable water in the various aerosol systems

Aerosols data are optical depth measurements. They are distributed in three quality levels: Level 1.0 (gross measures), Level 1.5 (cleaned measures, made without cloud), and the level 2.0 (Quality measures ensured by a second calibration). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality control.

3.4.4 How to do ?

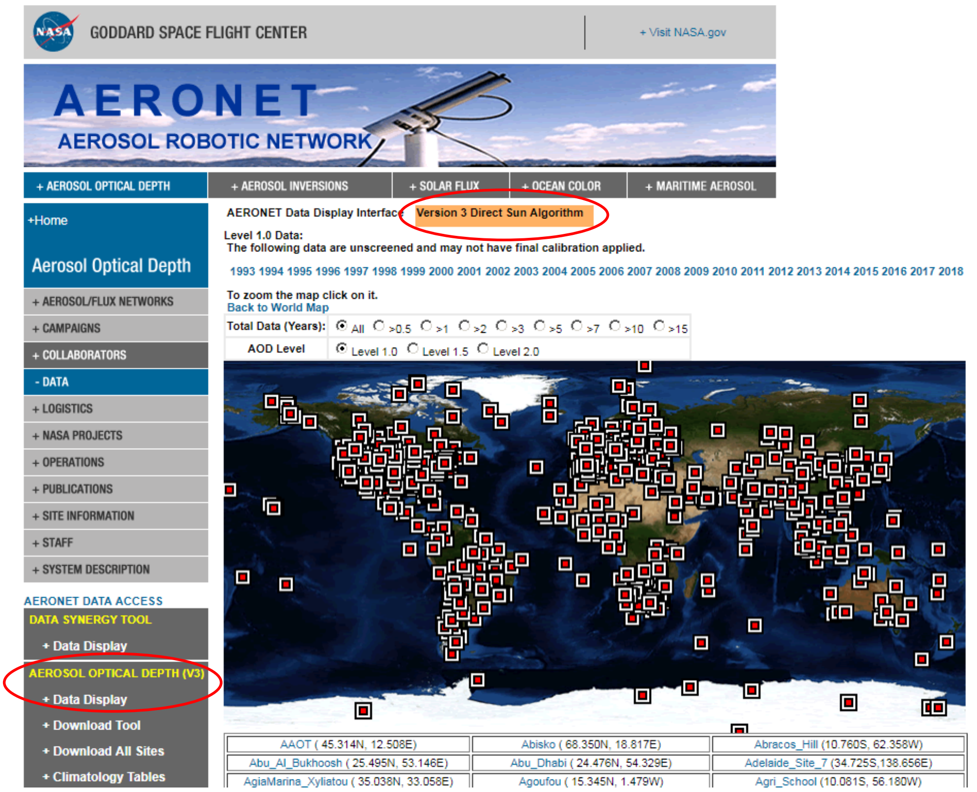
The first thing to do is find the Aeronet station nearest to the place where you plan on making your measurements. A distance of 20km between you and the site Aeronet seems to be a maximum for the validity of the operation.

You will find the location of internet stations :

https://aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_aod_v3

Perform measurements with the Calitoo to be calibrated by a sunny weather and a stable atmosphere. The aim is to achieve these measures in the same weather conditions as the Aeronet station.

Once the measurements, it will download on the website of Aeronet, the data file containing the precious AOT :

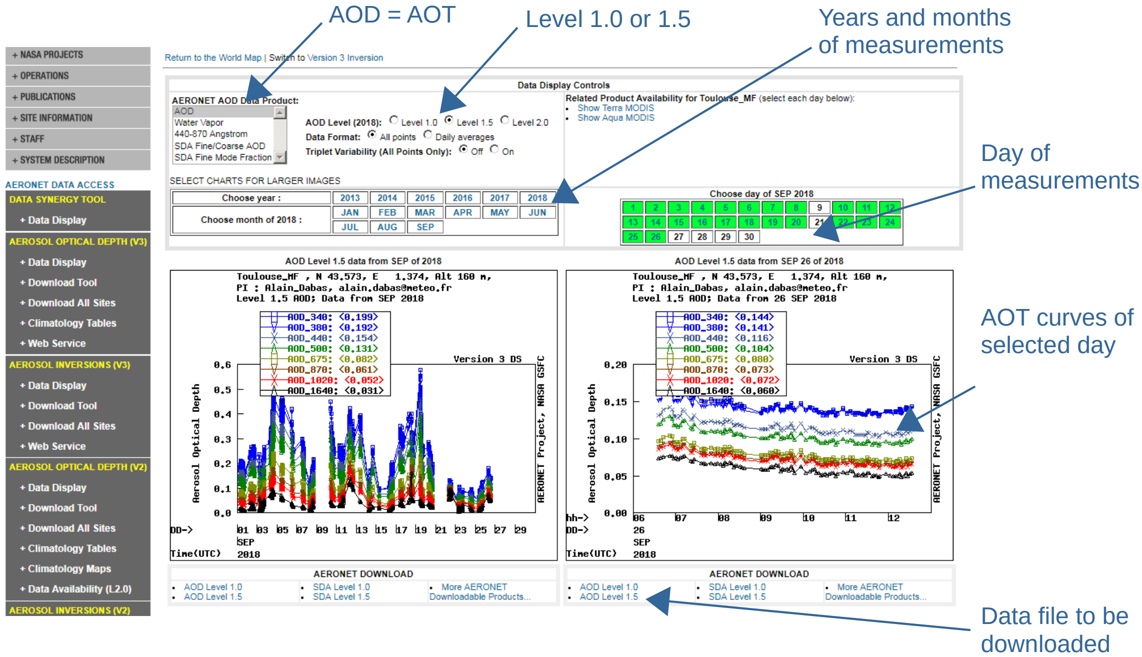


In the new version 2.9 of the Calitoo software, it is possible and recommended to use Aeronet data **version 3.0 Direct Sun Algorithm**

The software remains compatible with Aeronet version 2.0 files.

Select station with the help of the map and the name suggested in the table below.

When you are on the page of your Aeronet station (Example: Toulouse_MF), select the desired data type: AOD (Atmospheric Optical Depth = AOT) and *Level 1.5* if possible (to have only valid and not given those taken with clouds), otherwise *Level 1.0*.



You can view the curves of AOT on the site, to see if they are fairly horizontal (sign of a stable atmosphere during the day measures).

Download

Finally, you will need to upload the file (.zip) to your Download folder and integrate it into the Calitoo package according to the procedure presented in Step 2, paragraph 3.4.5 on the next page.

The name of a data file uses the following syntax :

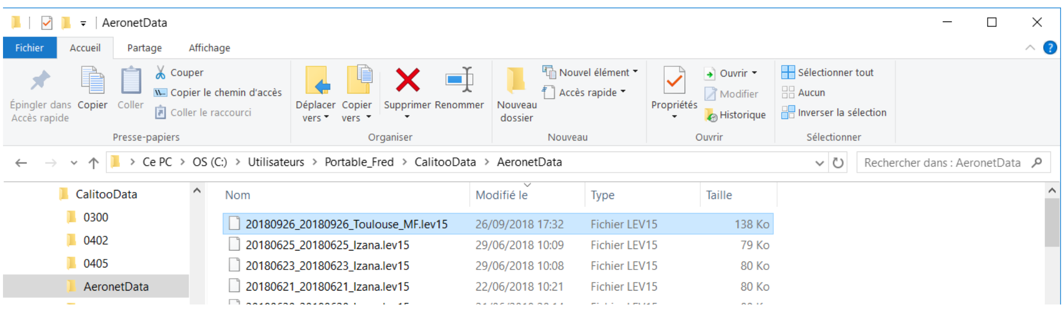
YYYYMMDD_YYYYMMDD_STATION.levNN

with: YYYY :year MM :month DD :Day

NN : data lev (10 for 1.0, 15 for 1.5 and 20 for 2.0)

For our example shown above, we downloaded the file :

20180926_20180926_Toulouse_MF.lev15



3.4.5 Inter-calibration with software

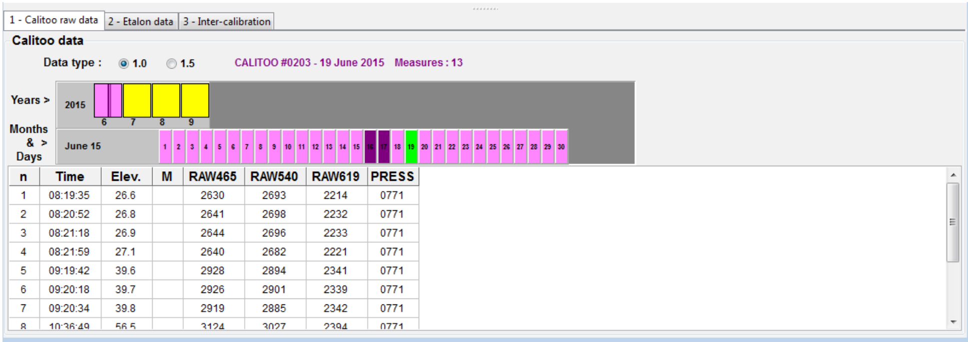
We assume photometers the data has been downloaded on your computer and the Aeronet data file, copied to the *AeronetData* folder.

The operation takes place in three steps: choice of photometer calibration data, choice of reference data and finally, calculations and results display.

These steps are presented in the form of three tabs in the lower part of the window :

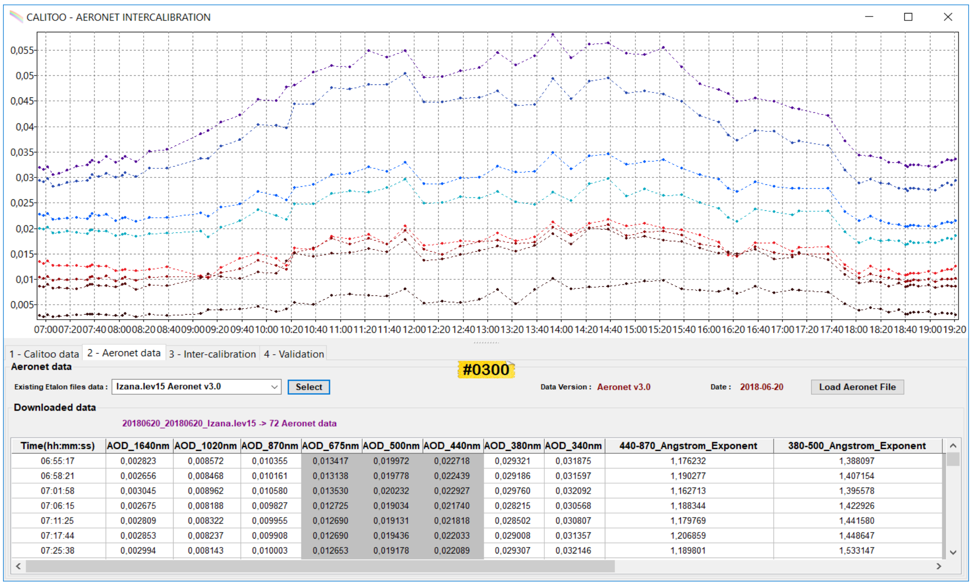
Step 1 : (*Calitoo raw data*) Data of Calitoo to be calibrated.

It consists in choosing the raw data in accordance with the measurement recording date with the calendar interface.



Step 2 : (Aeronet *data*) Data of reference photometer.

To use Aeronet files, you must download them (See Download) and integrate them into the Calitoo package: click on the *Load Aeronet File* button and go find the downloaded file of your choice.



After having chosen the file of the place that suits you, you must validate your choice by clicking on the *Select* button.

Aeronet's AOTs are then displayed, for information purposes, in the form of curves.

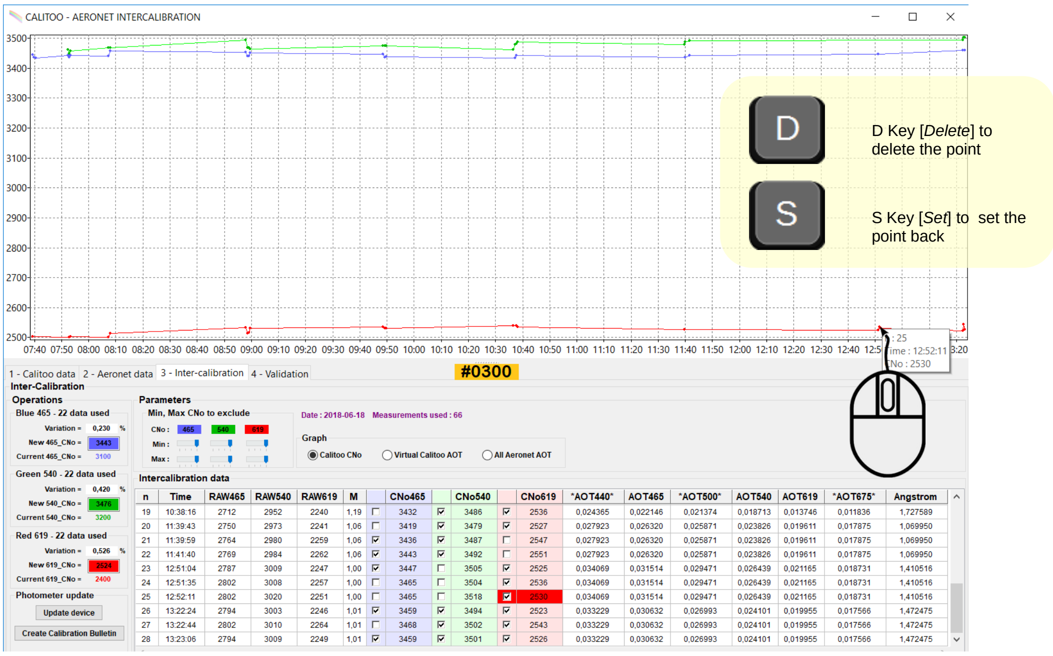
Please, note that the Aeronet reference photometer data files are located in the folder `<username>/CalitooData/AeronetData` .

Step 3 : (Inter-calibration) Results and update the photometer.

The penultimate step presents the results of the inter-calibration calculations : the three new CNo coefficients of Calitoo (New 465_CNo for blue for example).

The curves drawn represent the different CNo calculated. For each wavelength, you will try to have a curve as close as possible to a horizontal line.

It is possible to go in this direction by eliminating the extreme points (min and max) of the curve. To do this, use the small sliders in the Parameters panel. (Min, Max *Cno to exclude*) which allow to process up to 6 extreme points per wavelength.

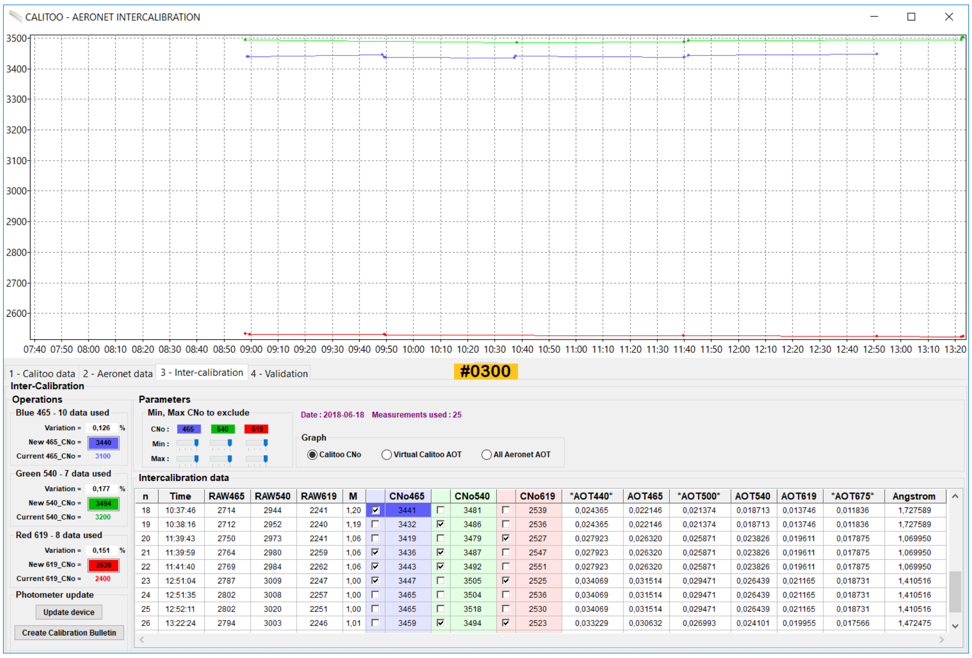


You can continue manually by pointing the mouse at the point to be processed and then pressing the[D] key to delete it or the[S] key to replace it.

The objective is to obtain variations of less than 0.200% for each color.

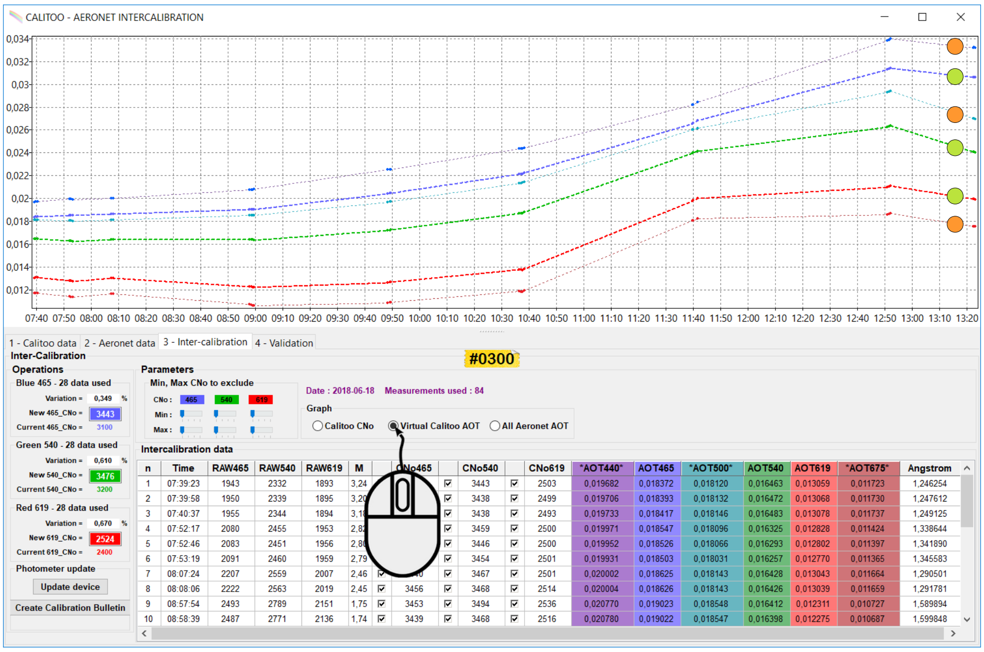
However, we consider that the calibration will not be statistically valid with a number of points lower than 6.

Here is the result of the search for the new calibration CNo (New Cno) :



Further information

Before updating your photometer, it is possible to evaluate the data used for calibration, the Virtual Calitoo AOT button allows you to view the curves of the Calitoo AOTs recreated from the Aeronet data :

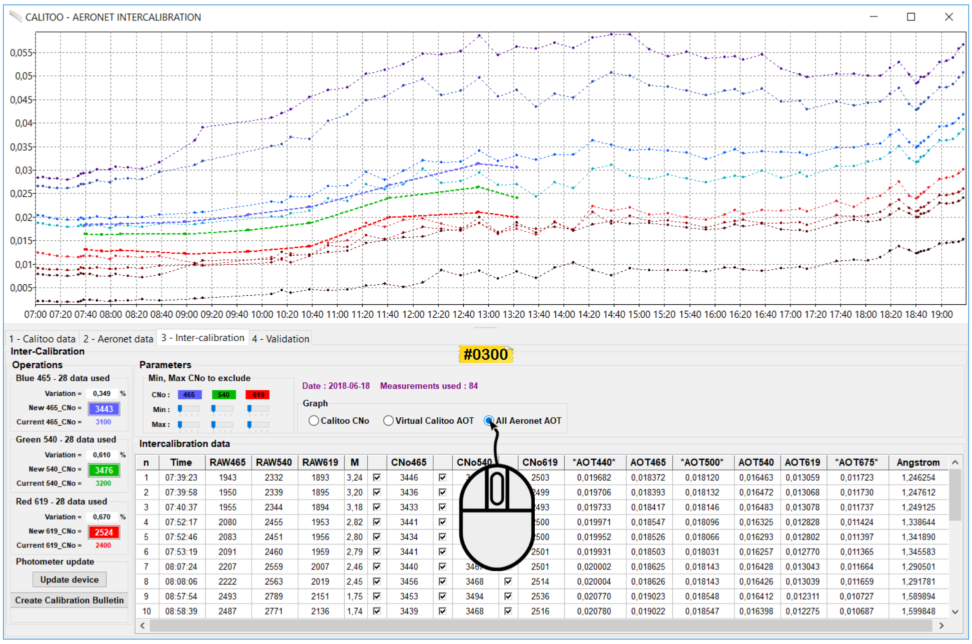


- Aeronet data used for the calculations.
- Virtual AOTs calculated at the same wavelengths of the Calitoo to allow inter-calibration.

  From the virtual AOTs, we do the reverse calculation of what is done in the Calitoo to find CNo for each wavelength and each measurement.

  It is these CNo's that are being sought to be standardized in the procedure described at the beginning of Step 3.

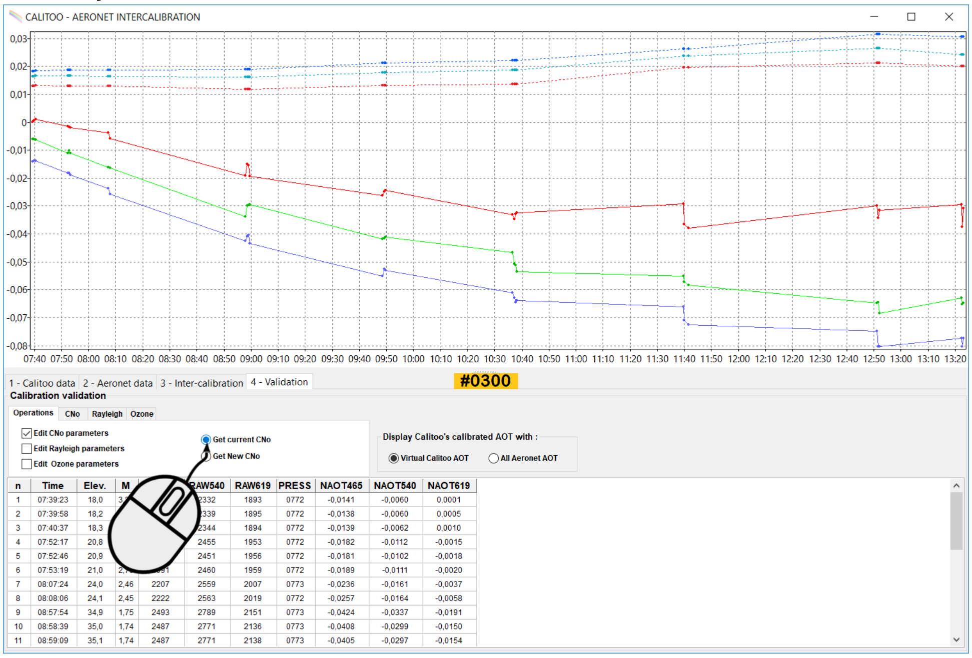
All Aeronet AOT provides an overview:



You can see the Calitoo virtual AOTs reconstituted among the other curves, which allows you to check the coherence of the whole:

Step 4 (Validation)

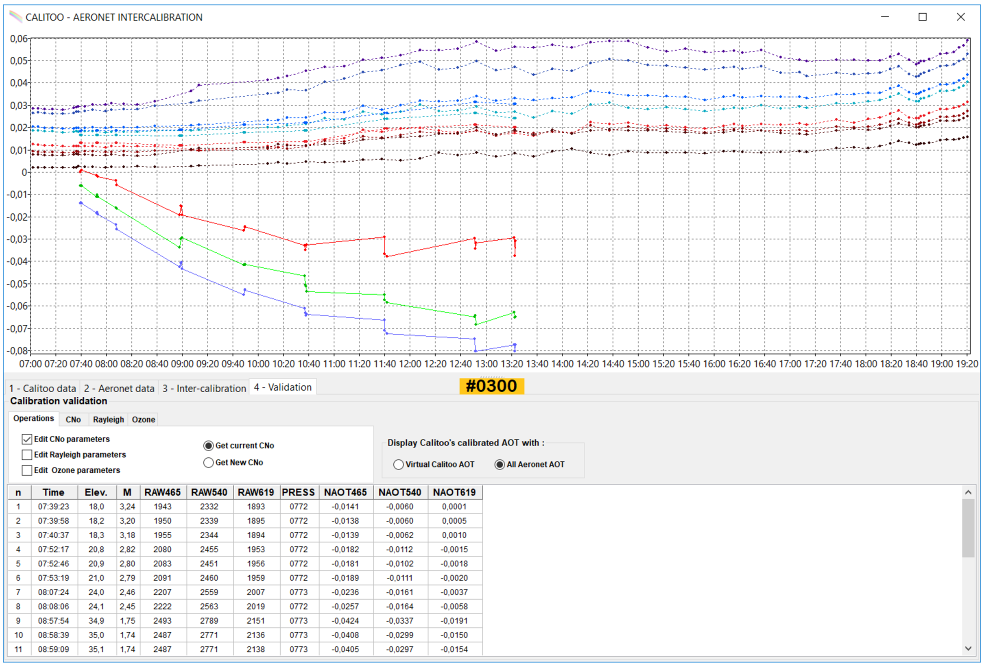
The last tab provides visualization tools that allow you to more accurately assess the validity of the inter-calibration.



The *Get current CNo* button displays what the measurements with the coefficients currently in the photometer (which is not yet calibrated) would look like.

We see on the graph that the curves (in solid lines) are very far from the ideal curves of the Calitoo virtual AOTs (in dotted lines). This is normal, the photometer is not calibrated.

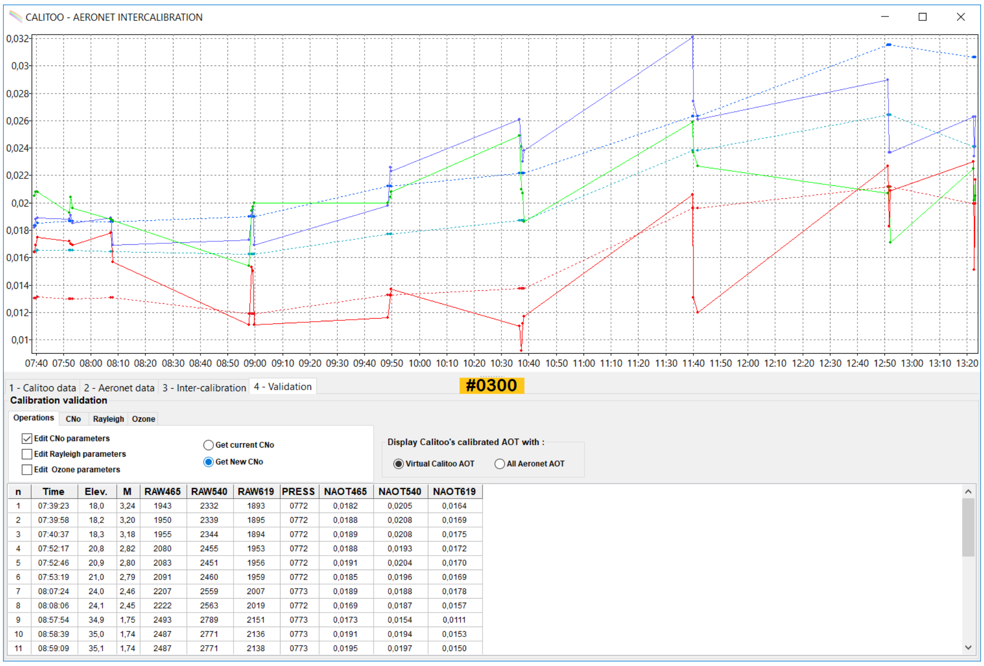
To get an overview of the curves, select the *All Aeronet AOT* button.



n	Time	Elev.	M	RAW465	RAW540	RAW619	PRESS	NAOT465	NAOT540	NAOT619
1	07:39:23	18,0	3,24	1943	2332	1893	0772	-0,0141	-0,0060	0,0001
2	07:39:58	18,2	3,20	1950	2339	1895	0772	-0,0138	-0,0060	0,0005
3	07:40:37	18,3	3,18	1955	2344	1894	0772	-0,0139	-0,0062	0,0010
4	07:52:17	20,8	2,82	2080	2455	1953	0772	-0,0182	-0,0112	-0,0015
5	07:52:46	20,9	2,80	2083	2451	1956	0772	-0,0181	-0,0102	-0,0018
6	07:53:19	21,0	2,79	2091	2460	1959	0772	-0,0189	-0,0111	-0,0020
7	08:07:24	24,0	2,46	2207	2559	2007	0773	-0,0236	-0,0161	-0,0037
8	08:08:06	24,1	2,45	2222	2563	2019	0772	-0,0257	-0,0164	-0,0058
9	08:57:54	34,9	1,75	2493	2789	2151	0773	-0,0424	-0,0337	-0,0191
10	08:58:39	35,0	1,74	2487	2771	2136	0773	-0,0408	-0,0299	-0,0150
11	08:59:09	35,1	1,74	2487	2771	2138	0773	-0,0405	-0,0297	-0,0154

Effect of your calibration on the data

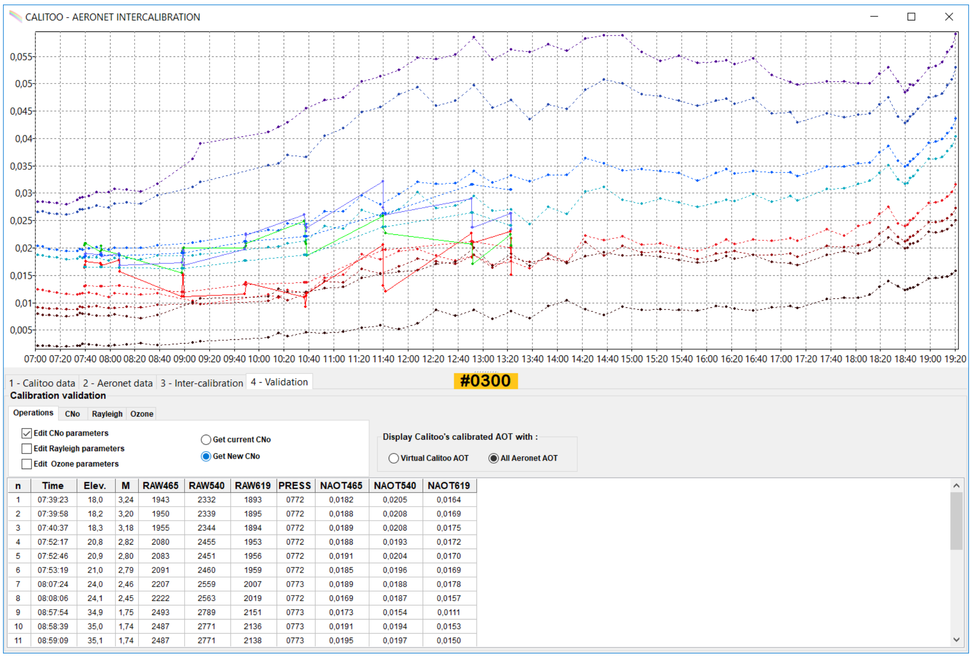
The *Get New CNo* button displays what the measurements would look like with the new coefficients from your current calibration.



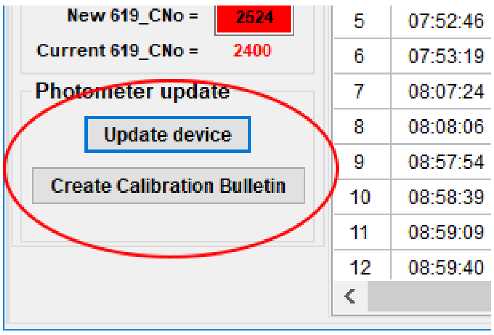
n	Time	Elev.	M	RAW465	RAW540	RAW619	PRESS	NAOT465	NAOT540	NAOT619
1	07:39:23	18,0	3,24	1943	2332	1893	0772	0,0182	0,0205	0,0164
2	07:39:58	18,2	3,20	1950	2339	1895	0772	0,0188	0,0208	0,0169
3	07:40:37	18,3	3,18	1955	2344	1894	0772	0,0189	0,0208	0,0175
4	07:52:17	20,8	2,82	2080	2455	1953	0772	0,0188	0,0193	0,0172
5	07:52:46	20,9	2,80	2083	2451	1956	0772	0,0191	0,0204	0,0170
6	07:53:19	21,0	2,79	2091	2460	1959	0772	0,0185	0,0196	0,0169
7	08:07:24	24,0	2,46	2207	2559	2007	0773	0,0189	0,0188	0,0178
8	08:08:06	24,1	2,45	2222	2563	2019	0772	0,0169	0,0187	0,0157
9	08:57:54	34,9	1,75	2493	2789	2151	0773	0,0173	0,0154	0,0111
10	08:58:39	35,0	1,74	2487	2771	2136	0773	0,0191	0,0194	0,0153
11	08:59:09	35,1	1,74	2487	2771	2138	0773	0,0195	0,0197	0,0150

We can see that the curves follow Aeronet's curves overall. The measured errors are in the order of 0.2% for AOTs of 0.02

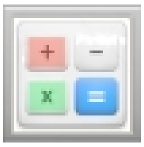
Similarly, to have an overview of the effect of our calibration, simply select the *All Aeronet AOT* button :



Once you are satisfied with your results, you return to the Inter-calibration tab and update your photometer (provided of course it is connected) and create a calibration report.



3.5 AOT calculator



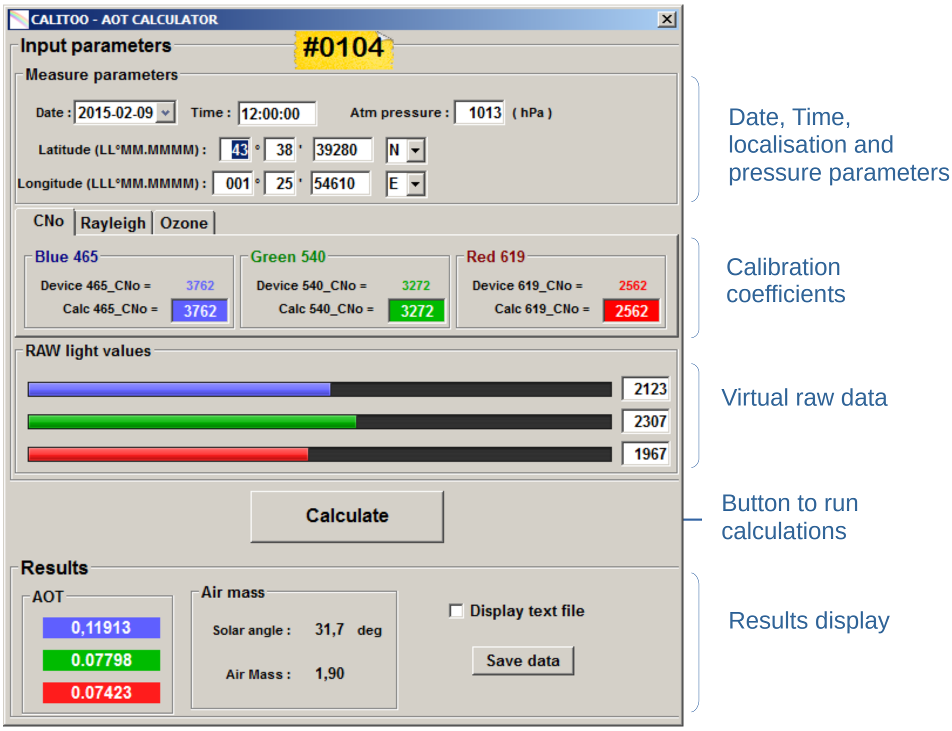
3.5.1 Principle

The idea is to provide a tool to study the influence of each parameter in the calculation of an optical thickness.

For example, with the same measurement, study the results to other latitudes, or study results with different CN_0 coefficient.

3.5.2 Calculation with the software

To perform AOT calculations, it is imperative to connect the photometer to the PC before starting the software. in fact, it is in the photometer that the calculations are made.



Calculation results are immediately readable. They are also available in a file to allow you to draw curves of study.

This file is located in the folder :

<*username*>/CalitooData/nnnn/

The file is named *CalculatorData.csv* and contains such information :

```
Date;Time;Pressure;Latitude;Longitude;B_Raw;G_RAW;R_RAW;B_AOT;G_AOT;R_AOT;B_CN0;G_CN0;R_CN0;B_Ray;G_Ray;R_Ray;G_Oz;R_Oz
2015-02-09;12:00:00;1012;4338.39280N;00125.54610E;1600;1600;1600;0.28800;0.30996;0.21143;3910;3530;2698;0.19490;0.10637;0.06119;0.0128;0.0154
2015-02-09;12:00:00;1012;4338.39280N;00125.54610E;1700;1700;1700;0.25618;0.27815;0.17961;3910;3530;2698;0.19490;0.10637;0.06119;0.0128;0.0154
2015-02-09;12:00:00;1012;4338.39280N;00125.54610E;1800;1800;1800;0.22619;0.24815;0.14962;3910;3530;2698;0.19490;0.10637;0.06119;0.0128;0.0154
```

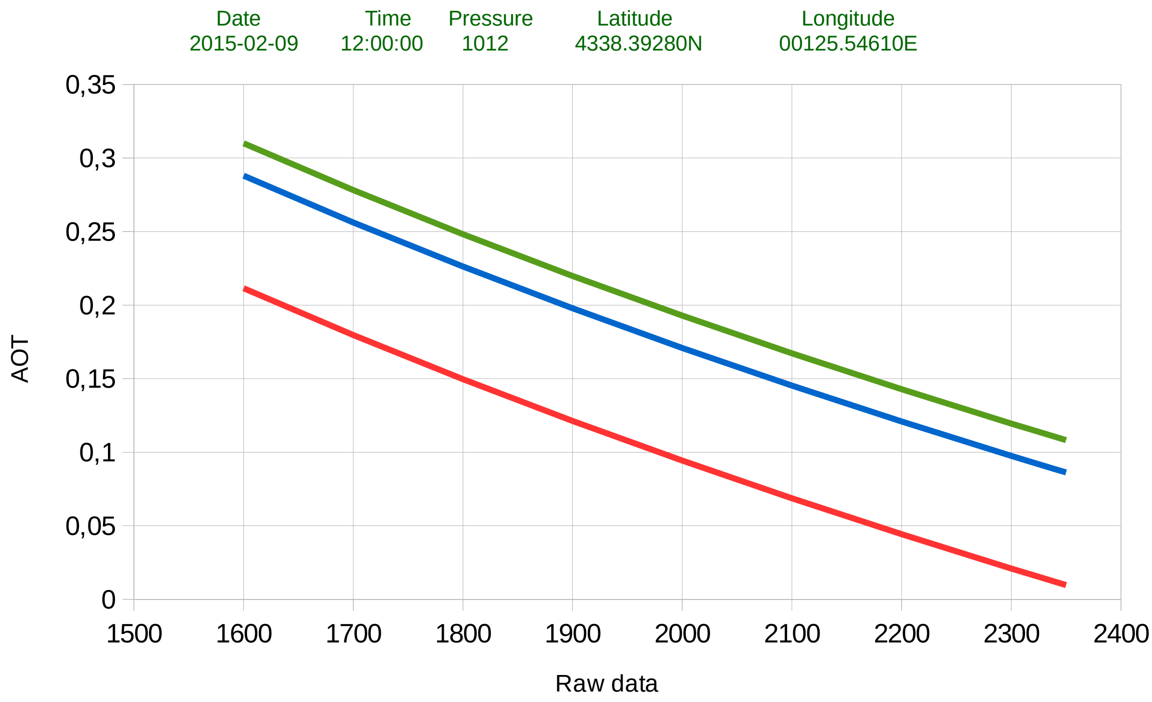
Ready to be imported into a spreadsheet.

Please note this file is unique, a new set of AOT calculations with writing results to a file will result in overwriting of the previous series.

3.5.3 Graphic plots

We want by example, to know the influence of raw measurements on the value of AOT.

AOT calculator and work on spreadsheets allows for this type curves for a place, a date and a fixed time :



3.6 AOT processing

3.6.1 Principle

The processing of AOT data retrieves old measurements and re-calculate the optical thickness based on new calibration coefficients.

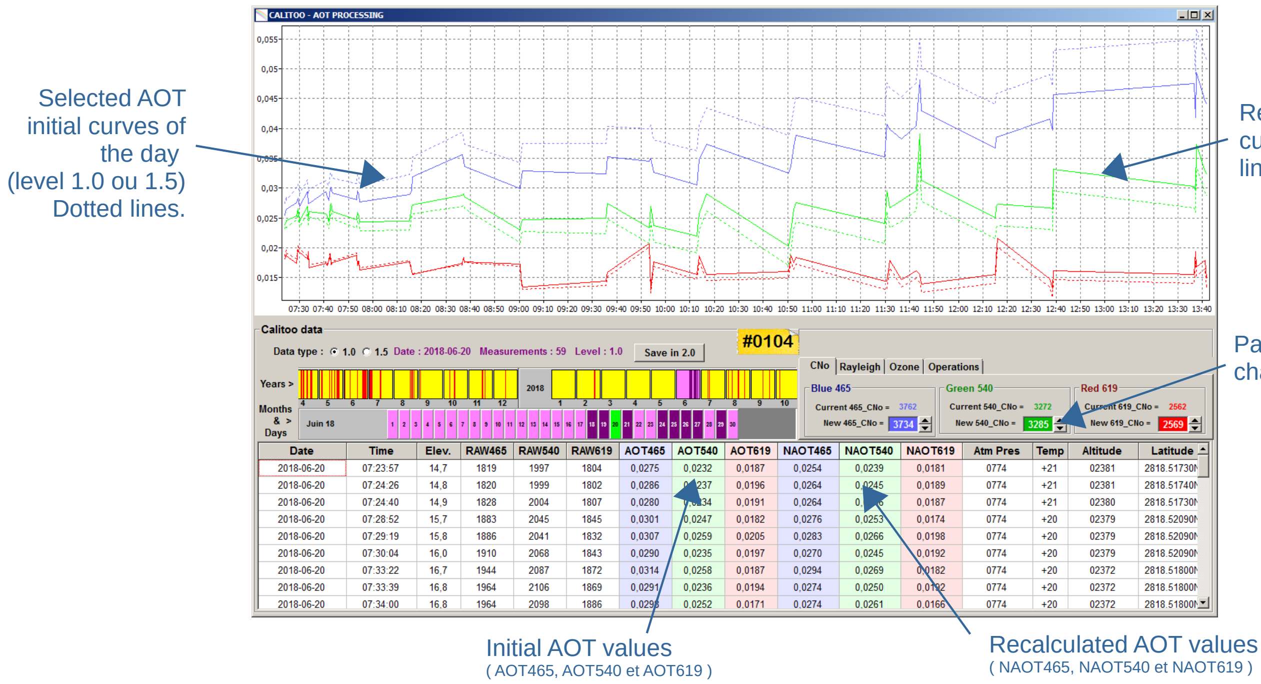
This will usually happen after a new calibration of the photometer. It can also be carried out on an experimental basis.

3.6.2 Re-calculation with software

After loading the data you want to work with, into the computer, click the tool icon *AOT Processing*.

The software displays the original AOT curves (dotted) and the curves recalculated from current coefficients in solid lines.

Here's what can be achieved on the screen :

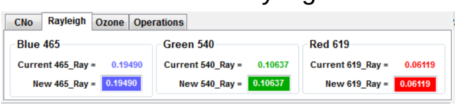


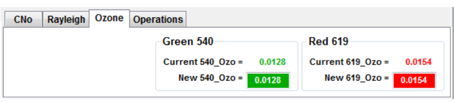
3.6.3 Change settings

The role of the parameters is quickly and easily readable: the curves are redrawn every variation of parameters.

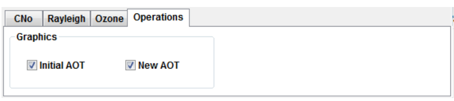
CN_0 with arrows

The coefficients of Rayleigh and ozone only with an editor.





Visualization of curves



However, for a re-calculation of AOT, you do not have a setting to change and they have already been updated with the new calibration.

3.6.4 Data writting

Data recalculated after a new calibration is saved by clicking the "Save in 2.0" button (level 2.0) in the xxxx_20 file for Calitoo No xxxx :

<*username*>/CalitooData/xxxx/xxxx_20/

Here, for example, the content of the file 2.0 photometer Calitoo # 0204 :

```
Calitoo #1506-0204 Level 2.0

------------------------------------------

CN0_465=3826;RAY_465=0.19490

CN0_540=3435;RAY_540=0.10637;OZ_540=0.0128

CN0_619=2733;RAY_619=0.06119;OZ_619=0.0154

----------------------------------------------------------------------

Date;Time;Temperature;Pression;RAW465;RAW540;RAW619;Altitude;Latitude;Longitude;Elevation;AOT465;AOT540;AOT619

2015-08-26;06:41:04;+20;0980;1244;1512;1440;00283;4310.38900N;00057.56890E;15.5;0.1067;0.0986;0.0916

2015-08-26;06:41:38;+20;0980;1298;1562;1514;00284;4310.38910N;00057.57240E;15.6;0.0971;0.0912;0.0792

2015-08-26;06:42:11;+20;0980;1420;1716;1645;00284;4310.38900N;00057.57250E;15.7;0.0746;0.0670;0.0577
```

3.7 Data exchange

3.7.1 Data exportation

The "Export" function collects all the data acquired with your photometer in a Zip file.

So, it’s easy to transmit all data in only one file on USB key or by mail.

To export, you must connect your photometer with the software, go into the toolbox and click on the icon (see above).

Choose where to write the Zip file to your computer and validate.

It is possible to export data from photometers whose data you have previously imported (see 3.7.2).

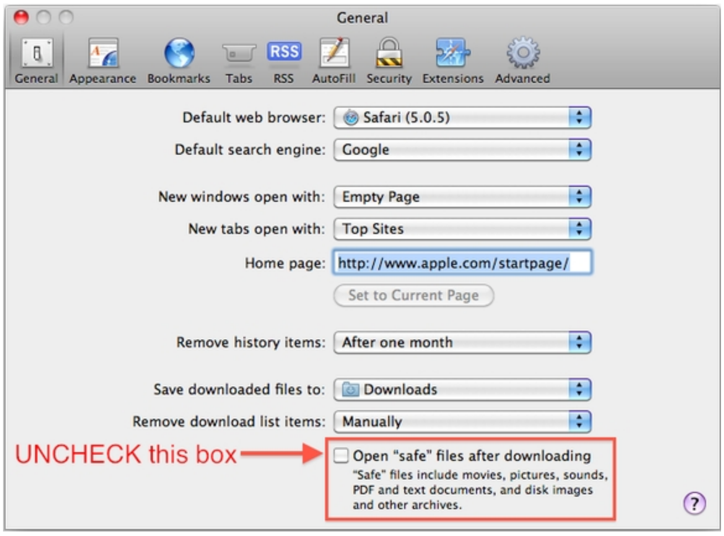
In this case, load the data as described in chapter 2.3.2 and proceed as before to access the export function.

3.7.2 Data importation

The complementary function of the preceding one allows to retrieve on his computer the data of a Calitoo of another observer who will have them exporter in the way described above.

The software tells you if data from the same photometer already exists on your machine. A validation will not destroy the old measurements, but they will eventually be complemented by the more sensitive data.

Note: on a Mac, if you use Safari to download a Zip data file, you should know that it will not be automatically unzipped from the option in the preferences :



3.8 Calinet to transmit your measurement to the server

3.8.1 Presentation

Calinet is a project to group the measurements taken by Calitoo photometers on a server and to allow online consultation of the data in the form of geolocalized graphs and to compare the results with aerosol images produced by satellites.

Calinet is currently hosted on a server at the University of Lille-1 and supported by Icare. It is inspired by its big brother, the aeronet network :

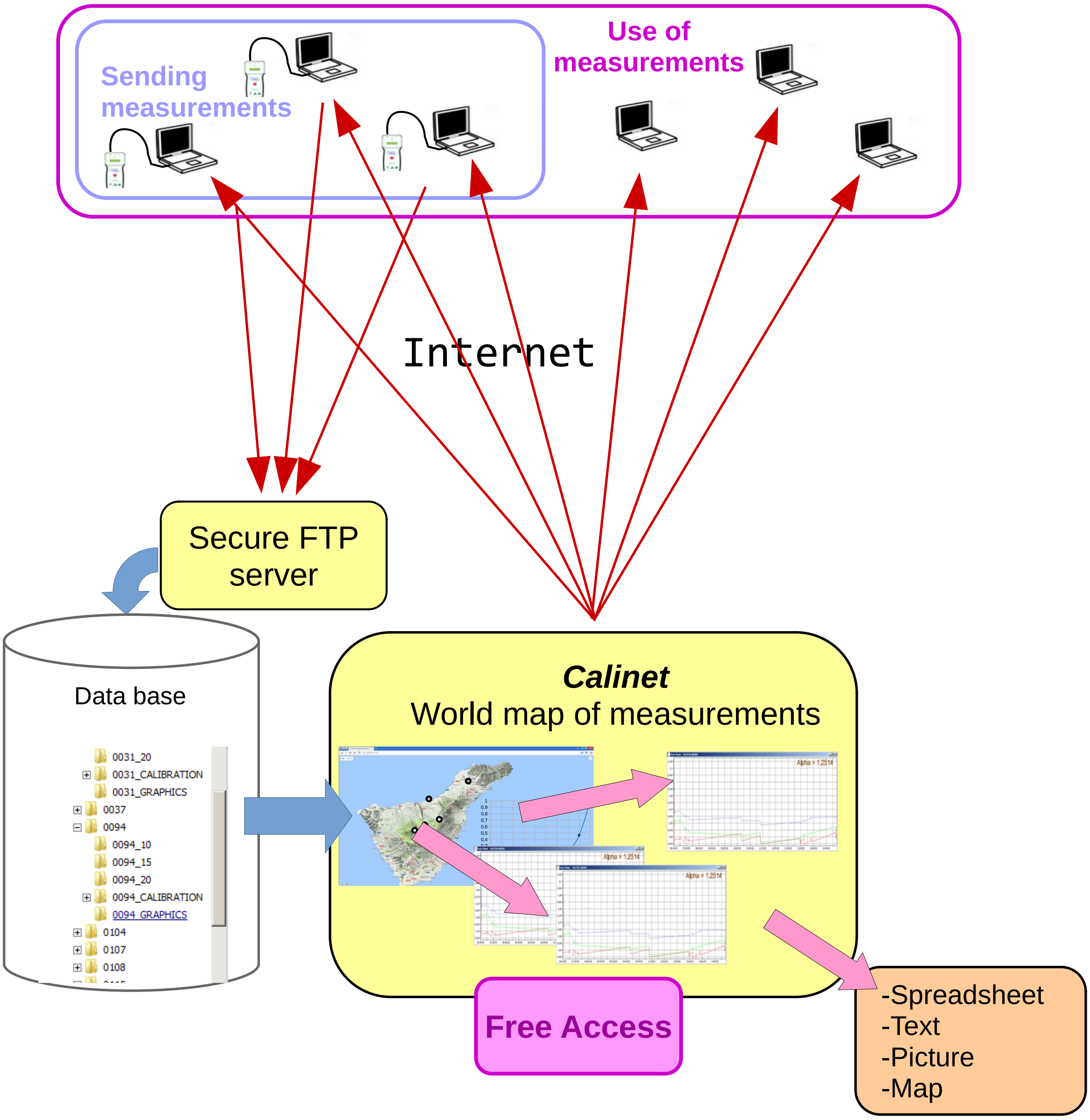
http://aeronet.gsfc.nasa.gov/new_web/index.html

Currently, there are 400 photometers spread over the 5 continents.

The deployment of photometers in schools and high schools is related to the Globe project, initiated by the United States: https://www.globe.gov/

Our scientific partners are also supporting the deployment of Calitoo around the world, particularly in West African countries for the study of the role of Saharan dust in climate change.

3.8.2 Architecture



The Calinet network should allow people to work with aerosol measurements from several geographically distributed Calitoo.

The work is done online and free of charge (no identification required).

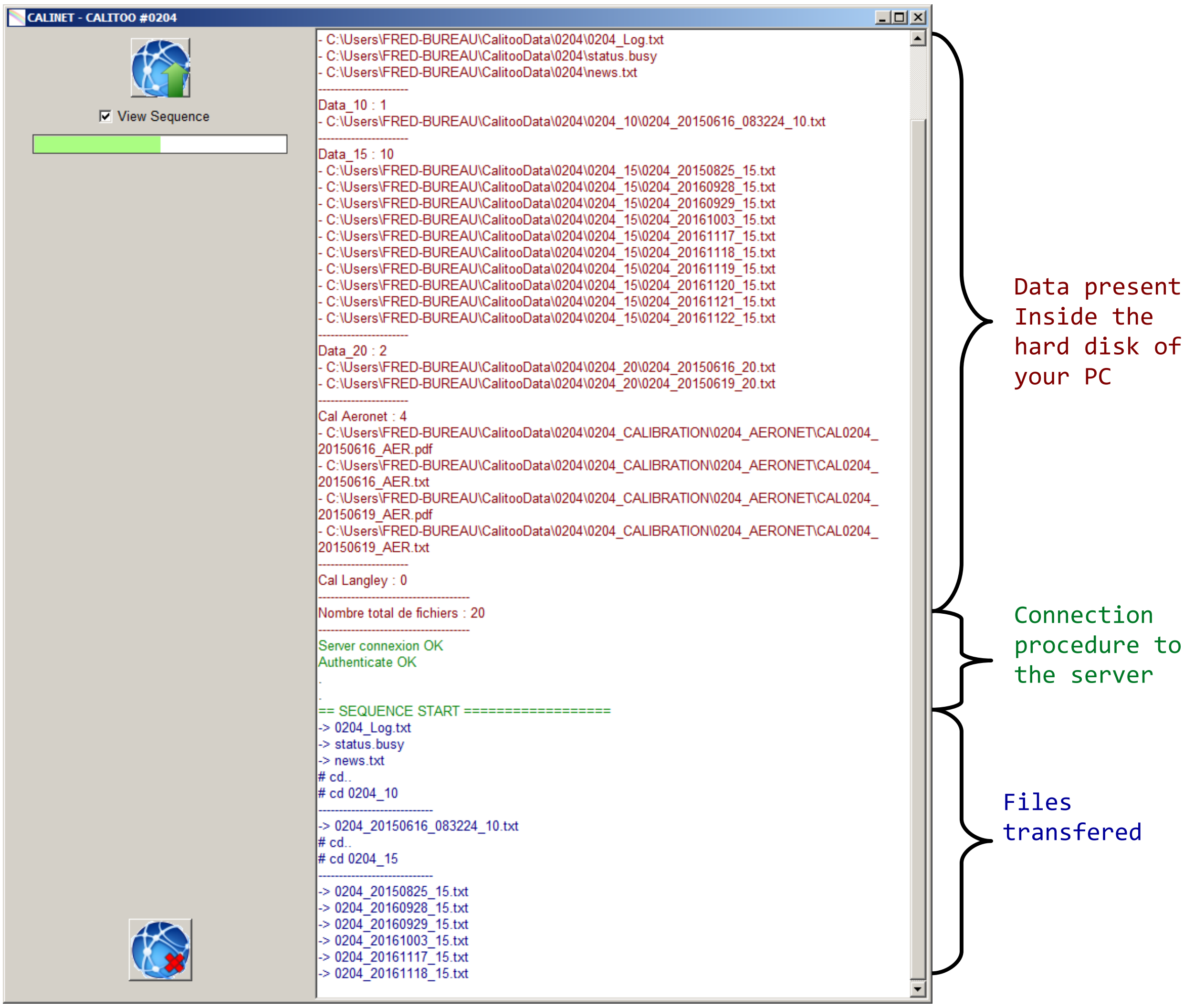
Calinet's objective is to produce summary documents presenting geolocalized and dated aerosol measurements in forms that can be directly used in a publication.

3.8.3 Transfer of measures

The software allows the user who has performed measurements, transferred them to his computer and processed them, to transmit them to the Calinet server by clicking on the icon : 

He has the option to monitor the file transfer and interrupt the transmission.

Transfer example :



A text file can be up to 100 KB (1000 measurements).

There are about ten files, so in general, one does not exceed by the megabyte of transfer.

The Calinet/Icare user manual is available on the Calinet server.

4 Appendix

4.1 Optical thickness calculation

Beer-Lambert law applied to the atmosphere

$$I(\lambda)=I_0(\lambda)\cdot\exp(-m(\tau_a+\tau_g+\tau_{NO2}+\tau_w+\tau_{O3}+\tau_r)) \quad \textbf{[1]}$$

I_0 : sunlight intensity outside the atmosphere

I : Light received on the ground

λ is the wavelength of light

τ_a : aerosols transparency coefficient

τ_g : gaz (CO_2 et O_2) transparency coefficient

τ_{NO2} : Nitrogen dioxide transparency coefficient (pollution)

τ_w : water vapor transparency coefficient

τ_{O3} : Ozone transparency coefficient

τ_r : Rayleigh scattering coefficient

m : Air mass coefficient through which light (optical path)

$$m=\frac{1}{\sin(\theta)}$$ θ is position angle of the Sun with the horizon

In the case of aerosols measures, the equation will be simplified by considering that the atmospheric optical total thickness depends only on the dissipation of the light by the molecules (Rayleigh) by ozone molecules (O_3) and aerosol . We distinguish the "natural" contribution (molecular) and "contaminating" (aerosols + others).

Contributions due to ozone (and perhaps other absorbing gases under certain conditions) and aerosols can be separated after the measurement or using climate data and average values of ozone depending on latitude eg , or by using the total of air column with the time and place of collection of the actual measurement data. Satellite mounted instruments such as the Total Ozone Mapping Spectrometer (4) (TOMS) provide such data.

(4) http://ozoneaq.gsfc.nasa.gov

Equation [1] becomes : $I(\lambda)=I_0(\lambda)\cdot\exp(-m(\tau_a+\tau_r+\tau_{O3}))$

We search to determine τ_a.

τ_r coefficient is proportional to the ratio of atmospheric pressure measured at the observation point by pressure measured by the level of the surface of the sea (p/p0) and therefore :

$$\tau_r=a_R\cdot\frac{p}{p_0}$$

τ_{O3}, coefficient is supply by LOA for green and red light length. In the blue light, this coefficient is null.

Our photometer returns a value directly proportional to the light intensity.
We will call : N.
If the photometer was outside the earth atmosphere (1 AU[5] of the sun) for measuring the brightness of the sun, it would give N_0 value.

(5) Astronomical Unit. It is equal to the average Earth-Sun distance (150 million kilometers).

$$N = N_0 \cdot \exp\left(-m\left(\tau_a + a_R \cdot \frac{p}{p_0} + \tau_{o3}\right)\right)$$

We will introduce a correction term taking into account the Earth-Sun distance varies depending on the day of the year.

$$N = N_0 \cdot \left[\frac{r_0}{r}\right]^2 \cdot \exp\left(-m\left(\tau_a + a_R \cdot \frac{p}{p_0} + \tau_{o3}\right)\right)$$

With $\boldsymbol{r_0}$, the distance of 1 AU and $\boldsymbol{r}$ then Sun-Earth distance at measure date (in AU).

$$r = \frac{[1-e^2]}{\left[1+e\cos\left(2\pi\frac{n}{365}\right)\right]}$$ Avec e = 0.0167

We now express τa, optical thickness due to aerosols, according to the other terms

$$\ln(N) - \ln\left(N_0 \cdot \left[\frac{r_0}{r}\right]^2\right) = -m\left(\tau_a + a_R \cdot \frac{p}{p_0} + \tau_{o3}\right)$$

$$\tau_a = \frac{\left[\ln\left(N_0 \cdot \left[\frac{r_0}{r}\right]^2\right) - \ln(N)\right]}{m} - a_R \cdot \frac{p}{p_0} - \tau_{o3} \quad [2]$$

The Aerosol Optical thickness is denoted AOT.

The part of this thickness created by aerosol is called Aerosol Optical Depth noted AOD

Calibration parameters

- N_0 parameters are determined by calibration (No_465 for blue, No_540 for green and No_619 for red)

- a_R is calculated :

  For CALITOO, this parameters are :

WaveLength (µm)	a_R
0.465	0.19490
0.540	0.10637
0.619	0.06119

- τo_3 : is supplied by le LOA - Aeronet

4.2 Particle characterization

It is possible to determine the distribution in number and size of the particles constituting the aerosol. These particles whose diameter is between 10-3 and 100 microns are particularly concentrated over the industrialized regions of the Northern Hemisphere.

The Ångström coefficient is a sensitive index to the size distribution of aerosols. It is inversely related to the average particle size of the aerosol particles are the more smaller, the exponent is high.

This coefficient is also a good indicator of the proportion of atmospheric precipitable water, where the aerosol concentration plays now recognized as a very important role. It allows to anticipate the volume expected in a season precipitation. Depending on the concentration of water present in the atmosphere, a higher coefficient of favoring the concentration of the clouds and rain.

Calculation :

The Angström coefficient α is calculated with Optical thickness data (τa_n) taken at two different wavelength λ_1 and λ_2 :

$$\tau a_1 = \beta.\lambda_1^{-\alpha}$$

$$\tau a_2 = \beta.\lambda_2^{-\alpha} \quad \Leftrightarrow \quad \tau a_1 / \tau a_2 = \lambda_1^{-\alpha} / \lambda_2^{-\alpha} \quad \Leftrightarrow \quad \log(\tau a_1 / \tau a_2) = -\alpha \, . \log (\lambda_1 / \lambda_2)$$

$$\Leftrightarrow \quad \log(\tau a_1 / \tau a_2) = \alpha \, . \log (\lambda_2 / \lambda_1)$$

$$\Leftrightarrow \quad \alpha = \log(\tau a_1 / \tau a_2) / \log (\lambda_2 / \lambda_1)$$

The typical value range α is from 0.5 to 2.5 with an average value of 1.3 for natural atmosphere.

Example :

Seysses, september 1st 2010 at 12h11:19 UT.

$\lambda_1 = 0.675\ \mu m$ $\qquad$ $\tau a_1 = 0.10$

$\lambda_2 = 0.532\ \mu m$ $\qquad$ $\tau a_2 = 0.13$

Calculation of α :

$$\alpha = \log(0{,}100 / 0{,}135) / \log (0{,}532 / 0{,}675) = \mathbf{1{,}126}$$

Note: Both neperian logarithms and decimal logarithms can be used. For consistency with the programs of Calitoo and the PC software which have their own computational constraints, the "Ln" have been replaced here by "Log" from the 2016 version of this document.

Aerosol global map : [Aerosol Size GlobalMaps]

Calculation of the linear correlation coefficient R^2

Prerequisites
The number of points : n
The coordinates in ordinate : x_n
The coordinates in ordinate : y_n

Step 1 : Calculation of the averages of the x_i and the y_i

$$M_x = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad M_y = \frac{1}{n}\sum_{i=1}^{n} y_i$$

Step 2 : Calculation of the variances of the x_i and the y_i

$$V_x = \frac{1}{n}\sum_{i=1}^{n} (x_i - M_x)^2 \qquad V_y = \frac{1}{n}\sum_{i=1}^{n} (y_i - M_y)^2$$

Step 3 : Calculation of the covariance of the (x_i, y_i)

$$Cov_{xy} = \frac{1}{n}\sum_{i=1}^{n} (x_i y_i - M_x M_y)$$

Step 4 : Calculation of the correlation coefficient R^2

$$r^2 = \frac{Cov_{xy}^2}{V_x V_y}$$

Step 5 : Obtain the equation of the regression line

Equation of type Y = aX + b

$$a = \frac{Cov_{xy}}{V_x} \qquad b = M_y - a M_x$$

#300 15 october 2017 n=3

	B	G	R	Averages	Variances
AOT	0,0981	0,0826	0,0815		
Log(AOT) (y)	1,0083309926	1,0830199527	1,0888423913	1,06	0,0013
Log(Lambda) (x)	2,6674529529	2,7323937598	2,7151673578	2,71	0,0008

Covariance
0,00095

Correlation
0,08678

4.3 Install with Windows

This software has been tested with success under Windows® 7, 8 et 10.

Start by downloading the archive file : `Calitoo_v2.9_windows.zip` from our website

http://www.calitoo.fr/index.php?page=logiciel-pc

Open the archive and extract the `Calitoo_v2.9` folder on your desktop.

Folder contents :

```
Calitoo_setup.exe
CDM21228_Setup.exe
2.9_Changes.txt
```

4.3.1 Installing USB-FTDI driver

This must be done before connecting for the first time the photometer to the PC via the USB port and Calitoo before starting the program.

We will install a driver that transforms the USB port to a virtual serial port.

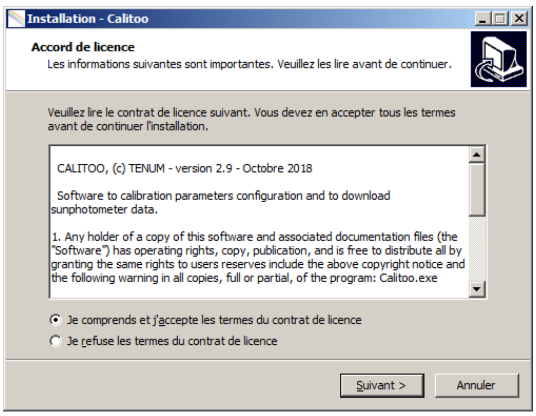
This requires run as administrator, the FTDI Driver file :

`CDM21228_Setup.exe`

Mouse right button on the Driver FTDI icon.

4.3.2 Calitoo software installation

Just click on the *Calitoo_setup.exe* and follow the prompts to install the program



4.4 Installation under Linux

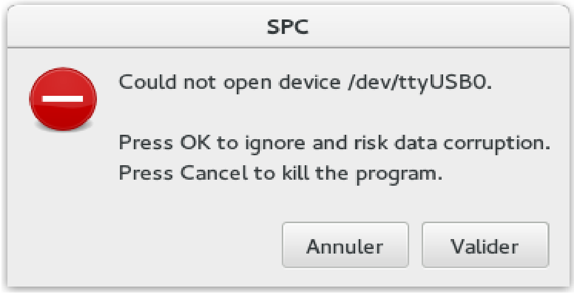
4.4.1 USB-FTDI driver configuration

With Linux, the FTDI driver is automatically installed, however some distributions for accessing the virtual serial port. It should ensure that you, as a user, you can access in reading and writing to this port. Here is an example with FEDORA :

When connecting a photometer by USB to a Linux PC, the system recognizes the driver and installs a new device in the / dev: among other files, we find :

/dev/ttyUSB0 which disappears when the photometer is offline .

This device is used natively by root and group dialout but not by any user who wishes to connect :



Connect and power a calitoo to the USB port of PC_Linux,

- Use a terminal and go to **/dev**

- Type the command: **ls -al**

- Identify in the dev list, the file **ttyUSB0**

You should have this:

```
crw-rw----.  1  root      dialout   188,    0   10 août   12:00   ttyUSB0
```

We will add a new rule that will allow read access and write to everyone in the device ***ttyUSB0*** :

skip as root : ***sudo -i***

In the folder **/etc/udev/rules.d/** create a file ***usbserial.rules*** in which add the following rule :

KERNEL=="ttyUSB0", GROUP= "dialout", MODE= "666"

By example, to edit enter : ***gedit usbserial.rules***

When **udev** will load the device **ttyUSB0** , it joins the **dialout** group (as previously) but now will assign permissions to read and write for everyone.

Reload the rules by typing : ***udevadm control –reload-rules***

Un-plug and re-plug the photometer.

Now when you view the folder contents ***/dev/*** with ***ls -al*** you read :

```
crw-rw-rw-.  1  root      dialout   188,   0   10 août   12:11   ttyUSB0
```

and when running the program, the connection to the USB port is now allowed for all users of the machine

.

4.4.2 Software installation

This software has been tested with success under Fedora, Debian, Mint, Ubuntu.

Start by downloading the archive file : **`Calitoo_v2.9_Linux.zip`** from our website

http://www.calitoo.fr/index.php?page=logiciel-pc

Open the archive and extract the **`Calitoo_v2.9`** folder on your desktop.

Folder contents :

```
Calitoo
calitoo.ico
Calitoo.desktop
```

The program **`Calitoo`** is directly executable file.

We leave it to you to create links for a quick launch from the desktop of your Linux distribution.

4.5 Installation under Mac-OS

Downloading virtual disk `calitoo_v2_9.dmg` from our website :

http://www.calitoo.fr/index.php?page=logiciel-pc

Click on the file `calitoo_v2.9.dmg` icon to open virtual disk `calitoo_v2_9` on the desktop :

Folder contents :


```
Calitoo
Calitoo.app
FTDIUSBSerialDriver_v2_4_2.dmg
FTDIUSBSerialDriver_v2_2_18.dmg
```

4.5.1 Installing USB-FTDI driver

This must be done before connecting for the first time the photometer to the PC via the USB port and Calitoo before starting the program.

Two driver files are provided and must be used depending on the version of your MAC-OS X system

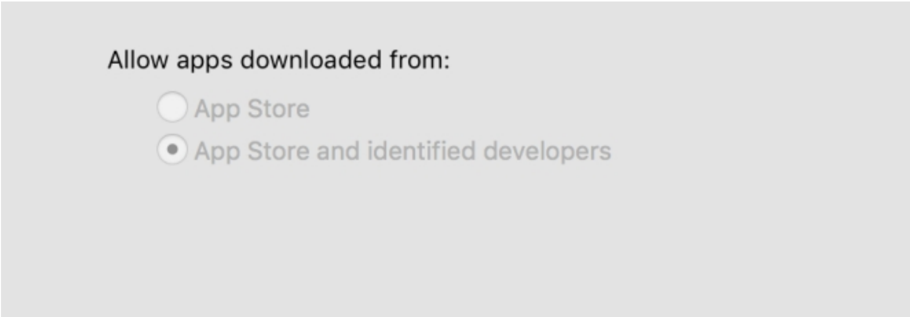
- Driver_2.2.18 for Mac OS X 10.3 to 10.8
- Driver_2.4.2 for Mac OS X 10.9 and above.

4.5.2 Software installation

There is no actual installation program : the software file is directly accessible in the virtual disk created by the downloaded *dmg* file.

First step : Enable the use of application downloaded from internet.

In recent Mac OS version, in *System Preferences / Security & Privacy* panel, there is no option "Anywhere" :



So, our Calitoo software cannot be open.

The solution is to retrieved this option by enter this command line under terminal (you have to enter your password) :

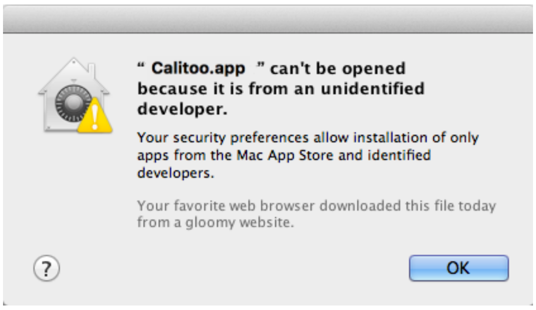
```
sudo spctl --master-disable
```

Then choose *Anywhere* option (Click on the lock to make changes if *Anywhere* is not selected).

Step 2 : Start Calitoo

Calitoo_v2_9 in the virtual disk, click the *Calitoo.app* file to start the program.

On first use, your Mac protection system probably tell you this :



It will just press the CTRL key while clicking again on the icon Calitoo.app

You have to click OK to continue until software startup.

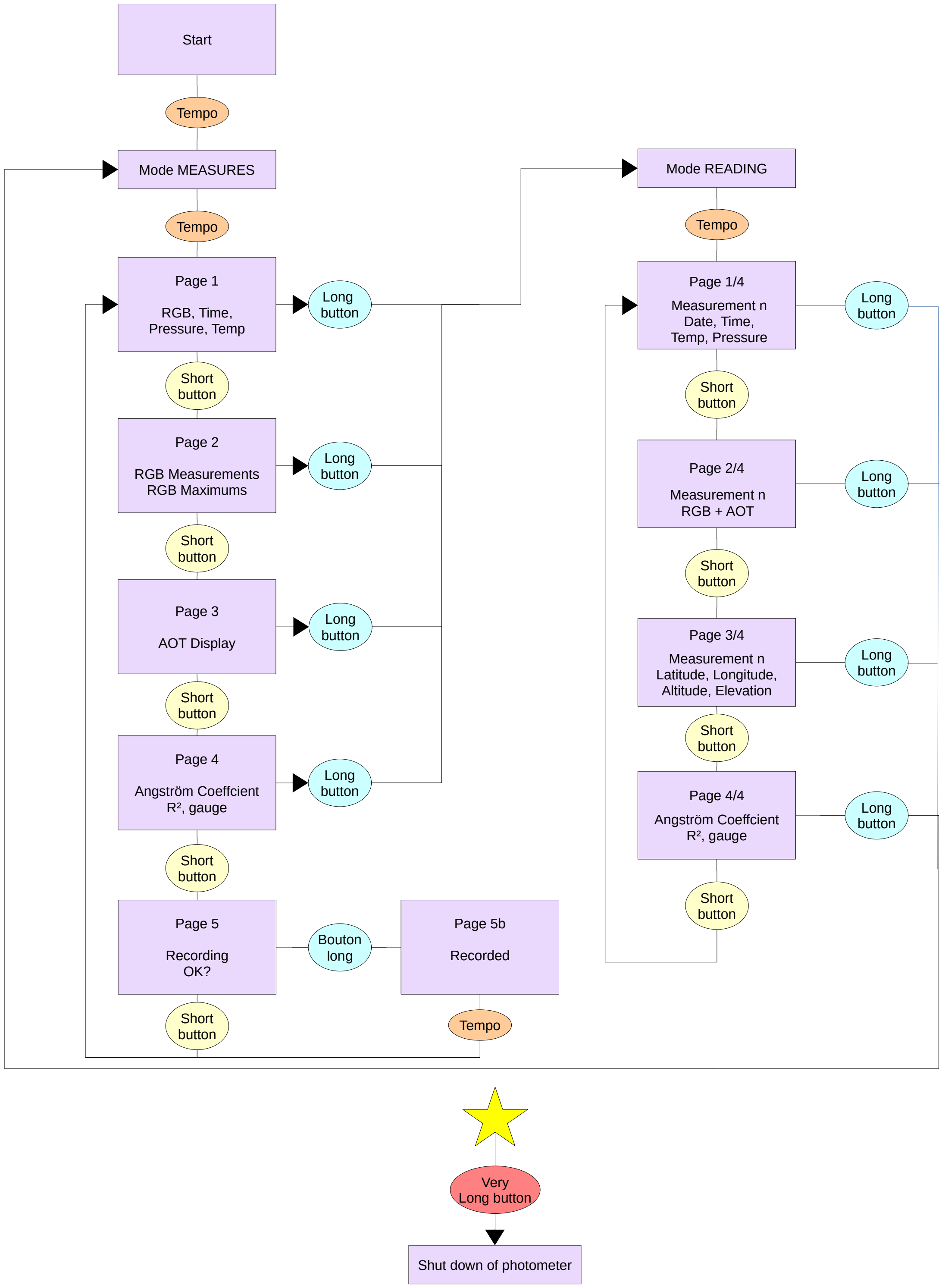
Now, you can Start Calitoo with Secondary Click (Right Click or ⌃CTRL+Click) on Calitoo icon (Rainbow) and choosing open (by selecting the checkbox to always easily start).

Step 3 : Protection restoration

After you have verified that Calitoo software run well, you can restore the security parameter by enter this command line in terminal :

```
sudo spctl --master-enable
```

4.6 Red button sequence on photometer



4.7 Organization of data into the computer

Working folder « CalitooData » is located at user folder root :

```
CalitooData
        0002
                0002_10
                        0002_20130912_133706_10.txt
                        0002_20130913_082411_10.txt

                0002_15
                        0002_20130905_1724456_15.txt

                0002_20
                        0002_20130905_1724456_20.txt

                0002_CALIBRATION
                        0002_LANGLEY
                                CAL0002_20130915_LAN.pdf
                                CAL0002_20130915_LAN.txt

                        0002_AERONET
                                CAL0002_20140908_AER.pdf
                                CAL0002_20140908_AER.txt
                0002_GRAPHICS
                        0002_20140908_15.bmp
                calculator.ini
                0002_log.txt

        AeronetData
                140908_140908_Izana.lev10
                140908_140908_Izana.lev15
                150618_150618_Izana.lev15

        Calitoo.ini
```

0002 : Identification number of the photometer it produced data found in this folder.

0002_10 : Folder of raw data of #0002 photometer. We used Aeronet nomination : 10 that is 1.0 for raw data. We never rewrite data in this folder, except during photometer data downloading.

1.0 = Raw data (digital light flux + AOT computed onboard the photometer).

1.5 = Unpleased data are deleted (Clouds, wrong pointage, manual filtering, etc).

2.0 = New computed AOT with new calibration parameters from a the last calibration campaign.

0002_20130912_133706_10.txt

File name is generated by the software.

The name is composed, by order :

Photometer number

Here is the #0002

Date of the first measurements of the file.

Here is September 12 2013 at 13:37:06 UT.

Data type (or level)

Here is 10 that is 1.0 of Aeronet level type.

Data file format

Photometer identification : Year, Month of manufacturing and unique order number.

Calibration parameters : (by example)
CN0_619 : No in red (619 nm)
RAY_465 : Rayleigh parameter in blue (465 nm)
OZ_540 : Ozone parameter in green (540 nm)

The ozone parameter is always null in blue color.

```
CALITOO #1310-0002
------------------------------------------
CN0_619=3945;RAY_619=0.06281;OZ_619=0.0154
CN0_540=3251;RAY_540=0.10637;OZ_540=0.0128
CN0_465=3250;RAY_465=0.19490
----------------------------------------------------------------------
Date;Time;Temperature;Pression;RAW465;RAW540;RAW619;Altitude;Latitude;Longitude;Elevation;AOT465;AOT540;AOT619;Alpha;R2
2013-09-12;13:37:06;+28;1006;2039;2132;1895;00154;4338.40656N;00125.57830E;43.4;0.1090;0.0929;0.0822;1.23;0.97
2013-09-12;13:37:37;+28;1006;2038;2130;1900;00148;4338.40957N;00125.57657E;43,3;0.1100;0.0939;0.0812;0.95;0,99
```

The name line of the data columns
RAW: raw digital measurements
AOT: optical thicknesses calculated in the photometer

Be careful, the decimal numbers will use the separator ('." or ',') of the host computer.

In its current version, the software for MAC-OS requires the'...' for separator regardless of the host computer settings.